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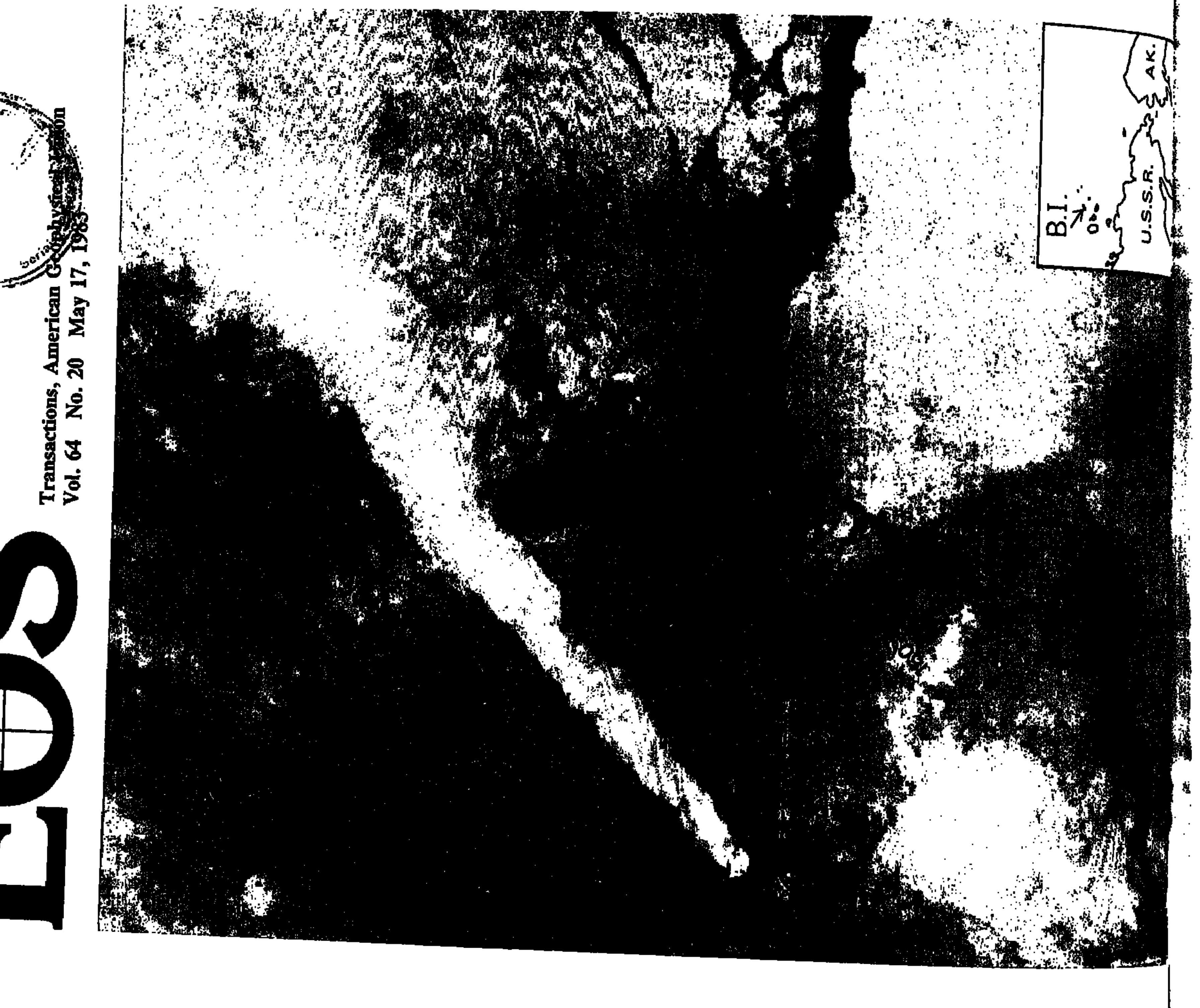

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IUGG Quadrennial Report Overviews

Planetary Science 1979–1982

Steven W. Squyres
NASA Ames Research Center, Moffett Field, CA 94035

It is not an exaggeration to say that the past 4 years have brought a growth in our knowledge of the solar system unprecedented in all of history. Prior to this quadrennium, our closeup exploration of the planets had been limited to the atmosphere and a few surface sites on Venus, the surfaces of Mercury, the moon, Mars, Phobos, and Deimos, and an intriguing but limited glimpse at Jupiter. To this list have been added the global topography of Venus and a wide variety of data on Jupiter, Amalthea, Io, Europa, Ganymede, Callisto, Saturn, Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, Iapetus, and Phoebe.

Among the recent discoveries are continent-sized landforms on Venus, a ring encircling Jupiter, the most volcanically active surface in the solar system on Io, hitherto unknown forms of global tectonism on icy Europa, Ganymede, and Enceladus, and intricate structure within Saturn's rings. Along with the spectacular growth in knowledge stemming from spacecraft exploration, major advances have also been made in telescopic observations of bodies not yet visited by spacecraft, radar observations of a variety of objects, and theoretical study of the evolution of both individual bodies and the solar system as a whole.

Pioneer Venus

The Pioneer Venus mission reached Venus in December 1978. It included an orbiter and four atmospheric probes [*Colin*, 1980]. The orbiter carried instruments that yielded data on the venusian particles and fields environment and on the upper atmosphere. It also carried the first radar instrument flown to the cloud-shrouded planet [*Pettengill et al.*, 1979]. This instrument showed most of the surface of Venus to consist of gently rolling plains, with a number of shallow, roughly circular depressions that may mark the sites of major, ancient impacts [*Masursky et al.*, 1980]. The plains separate several continent-sized highland regions with rugged topography that rises as much as 10 km above the lowlands.

The Pioneer Venus probes provided information about the venusian atmosphere that extended all the way to the planet's surface, including overall chemical composition, isotopic ratios, temperature, pressure, wind velocity, and direction, and cloud structure [*Donahue*, 1979.] This information considerably extended the knowledge gained from earlier Soviet surface probes. One surprising result is that the measured ratio of deuterium to hydrogen indicates a previous water abundance at least two orders of magnitude greater than at present [*Donahue et al.*, 1982]. Venus is not the twin of earth, but it may have once been much more nearly so.

Voyager at Jupiter

The most spectacular scientific results from this remarkable period have perhaps come from the Voyager mission to Jupiter and Saturn. The two Voyager spacecraft flew by Jupiter in March and July 1979. They provided the first high-resolution views of the jovian atmosphere and transformed the four Galilean satellites from points of light to mappable worlds.

Voyager observations of Jupiter have yielded the planet's upper atmospheric temperature structure [*Atreya and Donahue*, 1982], and have improved determinations of the atmospheric composition [*Hanel et al.*, 1979]. Voyager images have been used to track the circulation of Jupiter's atmosphere, showing a dominantly prograde flow with equatorial velocities of up to 150 m s^{-1} [*Smith et al.*, 1979 *a*, *b*]. Circulation within the Red Spot and other smaller oval forms has been characterized, and it has been possible to observe the detailed morphology of a variety of cloud features.

Voyager images of Io showed a varicolored orange and white surface interspersed with small, black spots [*Smith et al.*, 1979 *a*, *b*]. Shortly after the encounter, the startling discovery was made that volcanic vents on Io were propelling plumes of hot gas and dust as much as several hundred kilometers into space [*Morabito et al.*, 1979]. High resolution images show the black spots to be volcanic calderas and also show a diversity of rugged mountains and apparent tectonic features. The volcanic activity on Io was predicted just prior to the Voyager encounter on the basis of theoretical calculations of the dissipation of tidal strain energy [*Peale et al.*, 1979].

Voyager images of the ice-rich Galilean satellites Europa, Ganymede, and Callisto showed a remarkable diversity in appearance [*Smith et al.*, 1979 *a*, *b*]. Europa's surface is bright, extremely smooth, and laced with a pattern of darker, fracture-like markings. It has been proposed that tidal and radiogenic heating may be sufficient to maintain a substantial liquid water ocean under Europa's ice crust [*Squyres et al.*, 1983]. The surface of Ganymede shows polygons of old, dark, heavily cratered terrain separated by bands of younger, brighter, resurfaced, terrain. Much of the bright terrain contains topographic grooves that suggest an early period of extensional tectonism, perhaps related to a minor global expansion [*Squyres*, 1980.] The surface of Callisto is wholly dark, old, and heavily cratered, and the reason for the difference between Ganymede and Callisto is not well understood. As a final surprise at Jupiter, Voyager images showed a narrow ring of fine material lying in Jupiter's equatorial plane at a distance of about 1.8 Jupiter radii from the center of the planet.

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Voyager at Saturn

The Voyager mission continued with two encounters with Saturn in November 1980 and August 1981. As at Jupiter, data were obtained describing the thermal structure and composition of the upper atmosphere. Voyager images of Saturn's clouds confirmed a very strong prograde flow with equatorial velocities of up to 500 m s^{-1} [*Smith et al.*, 1982]. Saturn's northern and southern hemispheres, unlike Jupiter's, show a color asymmetry, which may be a seasonal effect. Ovals and wave forms are less prominent than in the jovian atmosphere.

Like the jovian satellites, the saturnian satellites showed considerable diversity [*Smith et al.*, 1981, 1982]. Mimas has a prominent, central peak crater nearly half the diameter of the satellite itself. Enceladus is perhaps the most unusual, with young, smooth regions free of craters at Voyager resolution and grooves like those on Ganymede. Enceladus' appearance may also be related to tidal heating [*Yoder*, 1979; *Squyres et al.*, 1982], and it is likely that Enceladus is the source of Saturn's tenuous E-ring [*Baum et al.*, 1980]. Tethys has a graben-like canyon extending nearly 270° around its surface. Rhea and Dione show bright leading hemispheres, slightly darker trailing hemispheres, and evidence for geologic resurfacing [*Plescia and Boyce*, 1982.] Images of Iapetus confirm its very dark leading hemisphere, and show an albedo pattern darkest exactly at the apex of orbital motion.

Titan, primarily because of its dense atmosphere, is in a class by itself. The clouds are generally orange in color and completely obscure the surface. The northern hemisphere appears slightly darker than the southern hemisphere, and there is a still darker hood over the north polar region. Several detached hazes are present above the main aerosol layer. Radio occultation data [*Tyler et al.*, 1981] combined with infrared results [*Hanel et al.*, 1981] indicate an atmosphere dominated by nitrogen, with smaller amounts of argon and methane. The surface temperature is roughly 95 K, and the surface pressure is roughly 1.5 bars (1.5 x 10^5 N m^{-2}).

Saturn's Rings

As might be expected, the greatest spectacle at Saturn was provided by the planet's rings. Most surprising was the wealth of fine detail within the rings. The general appearance of the rings is strongly reminiscent of that of a phonograph record, with concentrically arranged variations in particle density to the limit of Voyager resolution [*Smith et al.*, 1981, 1982]. Many of the features are clearly associated with satellite resonances. Recognized features include tightly wrapped, spiral density waves and vertical bending waves. Voyager radio occultation data show the ring particles to have an approximate power law size distribution, from 1 cm to a maximum of 1–5 m [*Tyler et al.*, 1982]. The thickness of the rings is at most 150 m, and probably several times less [*Lane et al.*, 1981].

Other surprising characteristics of the rings include kinks and multiple strands in the F-ring and transient, wedge-shaped 'spokes' that travel with the particles in the B-ring. The former probably results from gravitational interactions with two small satellites on either side of the F-ring [*Dermott*, 1981]. The latter may result from micron-sized particles being temporarily levitated from larger particles by electrostatic effects [*Smith et al.*, 1981, 1982].

Telescope and Radar Findings

A number of important findings have also resulted from telescopic observations. Infrared observations of the four brightest uranian satellites have yielded albedos of roughly 0.25–0.30 [*Brown et al.*, 1982], surprisingly low values considering the brightness of most saturnian satellites. Observations of Triton and Pluto show both objectives to be smaller than the earth's moon, bright, and with a surface that includes methane frost [*Morrison et al.*, 1982]. Pluto has been discovered to have a satellite, named Charon [*Christy and Harrington*, 1980].

Telescopic observations of asteroids have led to significant improvement in the taxonomic classification of asteroid families. The TRIAD data file, a comprehensive compilation of asteroid data, has recently been published [*Zellner et al.*, 1979]. Considerable controversy has arisen over the hypotheses that asteroids may in some cases be multiple objects or accumulations of unconsolidated rubble. Progress has also been made in the study of comets, particularly in the areas of their dynamic behavior and spectral properties. There is potential for an explosive growth in our understanding of comets with the impending return of Halley's comet in 1986.

Finally, substantial advances have been made in the use of earth-based radar to study the planets. Radar has been used for high-resolution imaging of Venus [e.g., *Campbell and Burns*, 1980] and determination of the topography of Mars [*Downs et al.*, 1982]. Observations of the icy Galilean satellites show extremely high radar reflectances and circular polarization ratios [*Ostro et al.*, 1980], which are not completely understood. The quadrennium has also seen the first radar detection of main belt asteroids [*Ostro et al.*, 1979] and of a comet [*Kamoun et al.*, 1981].

This brief summary has concentrated on the multitude of spectacular discoveries that have occurred in the past 4 years. Ultimately, however, the most important advances toward real understanding of the solar system come from indepth study of accumulated data. Two examples are the progress that has come from continued study of Apollo, Mariner 10, and Viking data and the substantial improvement that has taken place in the theoretical modeling of the formation and evolution of the solar system.

The future presents an opportunity for similar, detailed study of the wealth of new data from the past few years. With the expansion of space technology worldwide, it also presents the opportunity for the first truly international ventures to the planets.

U.S. National Report to IUGG 1979–1982

This issue of *Eos* contains the first 2 of 12 overviews appearing in the *U.S. National Report to the International Union of Geodesy and Geophysics 1979–1982*. The U.S. National Report is being published by AGU on behalf of the U.S. National Committee in four extra issues of *Reviews of Geophysics and Space Physics* (RGSP). The discipline overviews appearing here were published with their associated papers (see Contents list at the end of each overview) in the first U.S. National Report issue of RGSP (volume 21, number 2, March 1983); that issue also contains the overviews and papers covering Aeronomy and Cosmic Rays.

Issue 3 of RGSP will be devoted to the overviews and papers covering Geodesy, Geomagnetism and Paleomagnetism, and Hydrology; issue 5, Meteorology and Oceanography; and issue 6, Seismology, Tectonophysics, and Volcanology, Geochemistry, and Petrology. All four issues will have been mailed by July 1983. The four regular issues of RGSP are appearing as usual in February, May, August, and November.

Subscribers to RGSP will automatically receive the extra RGSP issues containing the U.S. National Report; those who do not subscribe to RGSP can still obtain the entire U.S. National Report by entering a subscription to RGSP. In addition, the report of each discipline will automatically be mailed separately to those members of AGU for whom that discipline is their primary AGU section affiliation; this separate distribution is made possible by grants from the Defense Mapping Agency, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, National Science Foundation, Office of Naval Research, and U.S. Geological Survey.

The remaining 10 overviews will appear periodically in *Eos* in the coming months.

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Contents: IUGG Quadrennial Report Planetology

Magnetospheric and Interplanetary Physics 1979–1982

David P. Stern
Planetary Magnetosphere Branch, Goddard Space Flight Center, Greenbelt, MD 20771

The quadrennium 1979–1982 witnessed notable advances in magnetospheric and interplanetary physics and demonstrated some major trends. Examples of both will be listed below, followed by an evaluation of the state of the discipline and of its future.

Standing out among the advances is the enormous volume of data about the magnetospheres of the giant planets collected by Voyagers 1–2 and by Pioneer 11. At the start of 1979 the very existence of Saturn's magnetic field was uncertain, and the role of the satellite Io in Jupiter's magnetosphere was only dimly guessed. Four years later we have extensive information on both magnetospheres, on their underlying planetary fields, ring currents, radio emissions, plasma composition, and nightside configuration, and about such matters as Io's plasma torus and the current filament linking Io to Jupiter, Saturn's inner radiation belt (from neutron albedo), and Titan's wake.

During the same interval great strides were also made toward tracing the behavior of different ion species in the earth's magnetosphere, charting the variability of different ions, and deducing their sources. The effort included widespread international collaboration, with key observations coming from European experiments. Much has been learned, but the data must still be extended to the 20–200 keV energy range, where most of the energy resides. Details have also come to light about the global distribution of 'beams' and 'conics,' and about the relative abundances of O^+, He^+, He^{++}, H^+ and O^{++}. Further properties of field-aligned voltage drops have been noted, including a suggestion of very narrow electric field structures, observable only with a millisecond time resolution.

Substorms

Auroral kilometric radiation was observed by ISEE-1 (and more recently by DE-1) in its source region, and considerable theoretical effort has gone into explaining its origin. Theory has also greatly advanced in computer simulation of global MHD flow in the magnetosphere. On the other hand, there was only modest progress toward understanding the magnetic substorm, where interesting statistical analyses were conducted on the correlation between interplanetary parameters and substorm activity related to the role of magnetic energy storage in substorms. Better information about the thickness and motion of the magnetopause was provided by the combination of ISEE-1 and -2, and ISEE also provided new evidence for magnetic reconnection on the day side.

New phenomena which still have to be placed in proper context include 'flux transfer events' at the dayside boundary, collimated beams along the boundary of the plasma sheet, the 'theta aurora' observed in the polar cap by the optical imager of DE-1, and some interesting changes in magnetic and plasma patterns observed in synchronous orbit near midnight just prior to substorm onset.

While substorms continue to attract attention, serious studies were also devoted to the quiet state of the magnetosphere during times of 'northward' interplanetary magnetic polarity. Several studies have suggested that even at such times the crosspolar potential does not fall below a baseline of about 30 kV, and that on occasion its usual two-lobed configuration is replaced by a four-lobed one. There has also been interest in the contracted polar cap at such times and in polar cap auroral arcs.

In interplanetary physics the study of the earth's bow shock has benefitted greatly from the ISEE spacecraft constellation, which among other things has provided new data about the foreshock, about waves propagating upstream of the shock, and about the role such waves may play in particle acceleration. On a larger scale, heliospheric observations now range from 0.3 AU (Helios 1–2) to 28 AU (Pioneer 10), with Pioneer 11, Voyager 1–2, and earth-based spacecraft at intermediate distances. During the quadrennium such data were combined with observations of coronal white light and of photospheric magnetic fields to yield definite results about the heliospheric current sheet and about the associated magnetic configuration around solar maximum.

New Instruments and Techniques

New instruments have meanwhile observed both the masses and the charge states of solar wind ions, noting both a high He^+ component in the driver gas behind shocks and an anomalously low He abundance at sector boundaries. Other new developments involve the correlation of shocks and coronal transients, new theoretical work on the origin of the solar wind, and observations of a tail-wake extending several AU behind the magnetosphere of Jupiter.

Notable new techniques during the quadrennium include growing use of electron beam experiments, including one aboard the STS-3 mission of the space shuttle in March 1982 whose results are still mostly unpublished. An 'active' experiment injecting into the magnetosphere radio waves of about 3 kHz, from Siple Station in Antarctica, has yielded many interesting observations, and the 'Cameo' barium release from orbit demonstrated both a new way of generating ion jets and the existence of large correlated structures of $E_\parallel$. Other technical advances involved auroral radars and ionospheric modification. As these lines are being written, data analysis from the twin coplanar DE spacecraft is just beginning, and the ISEE-3 spacecraft has moved into the earth's distant magnetic tail, an important region about which only sparse information exists. These and other achievements are described more fully, with appropriate citations, in the 11 reports that follow.

Outlook

What about long-term trends? More and more, physicists are led to combine data from a network of widely separated spacecraft to study phenomena (e.g., substorms) which no single spacecraft can adequately observe. Our observing network may have reached a peak at the beginning of the quadrennium, around 1979: Never before has the magnetosphere seen such an impressive array of diverse spacecraft in different orbits—the 3 ISEEs, IMP 8, SCATHA, AE-5, GOES 2–3, plus international spacecraft such as ISIS 1–2 (Canada), Kyokko and Jikiken (Japan), GEOS 1–2 (ESA) and the Prognoz series (USSR), plus 'piggyback' scientific instruments aboard Tiros, the DMSP series, ATS-6, and others. It was a fitting finale for the International Magnetospheric Study (IMS) [*Russell and Southwood*, 1982], and in view of the worldwide economic belt-tightening, this level of activity is not likely to be exceeded for some time.

If this great body of observations is to be used as a single, correlated data set, large computers, sophisticated programs, and wide-ranging cooperation are essential. The past quadrennium has shown that none of these are easily achieved. Coordinated Data Analysis Workshops (CDAWs) organized by the National Space Science Data Center in Greenbelt, around selected, short (~24 h) time intervals [*Manka et al.*, 1982] have demonstrated the extent to which the data analysis task overshadows existing methods of data display and analysis and of modeling physical processes. Even two-spacecraft correlations between ISEE 1 and 2 have been far fewer than what was earlier envisioned.

Data Analysis

In coming years the schedule of new missions is likely to be rather modest, and this is regrettable: As scientific problems are better understood and more accurately defined, additional new missions, such as AMPTE, Galileo, and the proposed OPEN mission will be needed in order to shed new light on them. The magnetospheric science community, however, may well devote more of its time to analyzing the data backlog 'awaiting disclosure in data freight yards and tape libraries' [*Greenstadt and Fredricks*, 1979, sec. 7]. On no account should any part of this data set be discarded or allowed to become unusable until that analysis is completed.

The problem has several aspects. The sheer volume of data requires extensive memory and computing power, such as only now are becoming available. Furthermore, data networks, summary plot information and data-handling software must be developed [*Smith et al.*, 1981]. Beyond that, however, ways must also be found for using those new tools efficiently. For instance, existing models of the magnetospheric B are still not far removed from those devised by Gauss, while the stacked plots and many-colored spectrograms so often encountered in the literature testify that no one has yet devised a concise method for handling multidimensional data. It sometimes seems that the resources of the magnetospheric science community are stretched thin by the great data-handling demands. Thus, even though the importance of AE indices is generally acknowledged, such indices have been compiled only for part of the quadrennium.

Beyond this, a great need exists for consolidating past gains of magnetospheric and interplanetary physics. This year marks the 25th anniversary of the IGY, when the first artificial satellites were launched and the study of space physics jumped to its present high level. In those early days it was easy for newcomers to assimilate much of what was known and to advance to the forefront of research, and useful experiments could be built with only modest resources. Today's instruments and data systems are quite sophisticated, and the amount of scientific work being published swamps those who hope to keep up with it. To help newcomers (and perhaps also oldtimers who try to keep head above water!), texts, reviews, and courses are needed, especially in the theory, which now must be pieced together from numerous journal articles. Thus a recent theory institute [*Carovillano and Forbes*, 1983] should be viewed as a welcome step, and it is hoped that the following reports will also help fill those needs.

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News

Beyond the Golden Age

There is good reason to call the time period between Mariner 2's flyby of Venus to Voyager 2's encounter with Saturn "The Golden Age of Planetary Exploration." For a period of 20 years, through 1981, spacecraft were sent almost every month by the United States (and a lesser number by the Soviet Union). Overall, more than two dozen planetary bodies were studied during the program.

Questions are frequently raised about programs beyond the year 2000. More pertinent are questions about plans between now and then. The National Aeronautics and Space Administration's (NASA) Advisory Council Solar System Exploration Committee (SSEC) has attempted to answer some of these questions in its 1983 report on *Planetary Exploration Through Year 2000*. The report attempts to identify 'the essential attitudes of a viable program in planetary sciences' and to define 'new ways to reduce costs.'

The reasons for this approach are painfully obvious. The Venus Radar Mapper mission (VRM) instigated this year is the first new start that NASA has had authorized in years. Space missions with the sort of achievement record of the 'Golden Age' traditionally require long lead times. Without a new approach the U.S. space exploration program will soon be at an end. Beginning with the VRM, which is being fabricated from spare and used spacecraft parts, a series of new, efficiently planned missions is being formulated to constitute a modestly scaled but high-scientific-yield program. The SSEC has successfully provided a route to achieve the highest priority goals of a viable scientific space exploration through 2000.

The plan is based on extending knowledge of the solar system, knowledge which has been so richly expanded during the past two decades. The 'Core Program' includes the VRM, whose mission is to continue mapping unexplored regions of the surface of Venus, and the Mars Geoscience/Climatology Orbiter to determine the surface composition of Mars and thereby obtain global classification of the two most earth-like planetary bodies in the solar system. Also included in the Core Program are the Comet Rendezvous and Asteroid Flyby and the Titan (largest moon of Saturn) Probe/Radar Mapper. The schedule of these missions is as follows:

Mission	Launch	Data Return
Venus Radar Mapper	1988	1988–89
Mars Geoscience/Climatology Orbiter	1990	1990–92
Comet Rendezvous/Asteroid Flyby	1990–92	1994–2001
Titan Probe/Radar Mapper	1988–92	1995–97

Following the core program of four missions, subsequent missions to the inner planets, to small bodies, and to the outer planets are planned as follows:

The Mars Aeronomy Orbiter will investigate the interaction of the planet's upper atmosphere and ionosphere with radiation and particles of the solar wind.

The Venus Atmospheric Probe will provide definitive information on the abundance of major and minor trace components of the Venus atmosphere toward an understanding of conditions in the intersolar system at the time the planets accreted.

The Lunar Geoscience Orbiter will provide a global map of surface elemental and mineralogical composition, and other properties, and decide the question of the presence of condensed water and other volatiles in polar cold traps.

The Mars Surface Probe mission will establish seismic, meteorological, and geoscience stations on the Martian surface. These will determine the level of Martian seismicity, provide surface weather data toward an understanding of its climatic pattern, and will also provide detailed geochemical analyses.

The Comet Atomized Sample Return mission will provide a detailed elemental and isotopic composition analysis of gases and dust in the coma of a comet, data complementing that acquired by a Comet Rendezvous mission. Ideally, the material will be returned to terrestrial laboratories from the same comet observed by the rendezvous spacecraft.

The Multiple Mainbelt Asteroid Orbiter mission will initiate the exploration of asteroids by providing a detailed characterization of at least one such body while at the same time sampling the diversity of sizes and physical types.

The Earth-approaching Asteroid Rendezvous mission will characterize in detail a member of this class of bodies.

The Saturn Orbiter will address questions to the characterization of the Saturn satellites, ring systems and magnetosphere and provide the first time resolution of features, close approaches to poorly seen satellites, and additional radar coverage of Titan's surface.

The Saturn and the Uranus Flyby Probe missions will provide in situ determination of the composition and structure of the Saturnian and Uranian atmospheres and clouds for comparison with the Jovian case as determined by the Galileo probe.

The extensive anticipated accomplishments are exciting, perhaps awesome. Global mapping of the moon's surface may lead to a better understanding of its origin, and of the earth's—there will be a search for lunar solar reservoirs of water ice. First visits will be made to near-earth and mainbelt asteroids. Direct analyses will be made of Titan's atmospheric composition and structure; the results will provide insights to the prebiotic state of the earth's surface. Exploration of the atmosphere and surface of Venus, earth's sister planet, may lead to an understanding of the state of its geological development. The list of scientific goals goes on; explorations of Saturn, Jupiter, and of Uranus are on that list.—*PMB*

Coalinga Quakes

A magnitude 6.5 (Richter scale) earthquake hit the city of Coalinga, Calif., about 520 km southeast of San Francisco, at 4:42 p.m. (PDT) on May 2. The earthquake, the largest to strike the region in at least 100 years, occurred on the extreme eastern edge of the 105-km-wide zone of active faults that form the San Andreas system in central California, according to the U. S. Geological Survey (USGS). More than 1,500 aftershocks, including two that struck May 8 and registered magnitude 5.5, have continued to jolt the area.

No deaths were reported, but injuries exceed 45, according to James Brady of the U.S. Disaster Field Office in Coalinga. Damage, estimated at more than $30 million, has resulted in the displacement of more than 1,000 persons.

USGS scientists said that the fault responsible for the earthquake is of a different variety than the well-known San Andreas fault that is located 52 km west of Coalinga. The San Andreas is a major vertical fault along which most large earthquakes occur when there is a horizontal strike-slip movement, the USGS says. In contrast, the May 2 earthquake appears to have been generated on an ancient, buried coast range thrust fault that once separated the North American continent from the Pacific basin. Thrust fault movement causes one block to move over the other. The coast range thrust fault is tens of millions of years older than the San Andreas fault, according to USGS scientists.

Locations of the aftershocks indicate that movement along the coast range fault occurred over an elliptical zone that measures about 52 km x 9.7 km and is centered around the main shock. The focal point of most of the aftershocks is below 10.8 km in depth. Although the San Andreas fault was not directly involved in the Coalinga earthquake, readings from sensitive fault displacement meters along the San Andreas in the Parkfield, Calif., area indicate a displacement of 0.5 cm.

Discovery of the thrust fault, a previously unknown type in the area, leads scientists to believe that other buried faults exist in the region, according to a USGS spokesman. Locating such faults will be difficult because no ruptures appear at the surface. The magnitude of the May 2 quake and the reactivation of the ancient fault imply that the period of quiescence is over and that a period of larger earthquakes has begun, the spokesman said. Leonardo Seeber of the Lamont-Doherty Geological Observatory said that the increase in seismic activity in the area began about 1979.

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Cover. Major tectonic and morphologic elements in the western South American subduction zone. The seismic lines are labeled according to 1976 profiles. > symbols due west off Callao indicate ASPER stations; CDP: common-depth-point digital seismic line. A–P: Abancay–Pisco deflection; H–P: Huancabamba–Paita deflection. Note that the active volcanoes (solid triangles) are outside of the segment bounded by the two deflections. Illustration from 'Geophysical Data and the Nazca–South American Subduction Zone Kinematics: Peru–North Chile Segment,' by L. Ocola, in *Geodynamics of the Eastern Pacific Region, Caribbean and Scotia Arcs, Geodynamics Series*, vol. 9, edited by R. Cabré. Published by AGU. For more details on this new AGU volume, see the 'Books' section, p. 388.

Core Models

Newly formulated models of the earth's core have been described recently as 'simultaneously provocative and vexing' (R. Jeanloz, *Nature, 299*, 108, 1982). Part of the reason for this is that concepts about the earth's core are being rapidly updated.

That there is knowledge at all of a core results from the analysis of seismic data; such analysis is model-dependent. Further analysis of more extensive data results in new models; alternative approaches to the problems from theoretical geochemical considerations result in another type of model. The conjunction of such models may seem incongruous, but not so. A great deal is being learned about the geochemistry of processes that have a bearing on core formation. Significantly, there has been a simultaneous surge of improved seismic data and analysis.

The results are intriguing. Whatever geophysicists may have thought about the earth's core, its boundary with the mantle, its molten outer and solid inner sections, and the boundary between them, and even its composition, today's models are proving there are differences. Recent shear wave data have brought into question the nature of the core-mantle boundary. The new models do not allow for even a thermal layer (T. Lay and D. V. Helmberger, *Geophysical Research Letters, 10*, 63, 1983). Either the boundary is diffuse or there is a distinct layer, neither mantle nor core, where a distinct boundary had been thought to occur.

The outer core data still fits fluid model concepts; however, concepts of the inner core and the outer boundary are being changed. One possibility is that the depth to the boundary may be variable depending on the properties of seismic waves that are used to 'interrogate.' The core material may be in a conceptually new state such that the inner core may have the properties somewhere between those of a solid and a fluid (D. L. Anderson, *Nature*, April 1983).

The general concept of the earth's core is that it is mostly fluid, the inner-solid portion having diameter of about 1215 km. The old idea that the core is a iron–nickel alloy, like iron meteorites, has long since been dispensed with on experimental grounds; but that the composition is an iron alloy is still current.

One difficulty has been that core models have been constructed by attempting to fit one-atmosphere iron and iron-alloy data to seismic models. The appropriate properties of materials under conditions of the earth's core—(1.5–3.5 Mbar, greater than 3000°C) have never been determined. 'Very good' shockwave data on iron and iron melt are still uncertain by at least 1000°C (O. L. Anderson, *Philosophical Transactions of the Royal Society of London, A306*, 21, 1982).

Part of the interpretation problem results from iron and its melt being almost indistinguishable in a shockwave experiment. The category of properties that could render iron to appear as fluid or solid in shear strength terms, that is, depending on the frequency of a seismic wave, could indeed characterize the 'outer' parts of the inner core.

A new twist on modelling the core's composition is that certain light elements, oxygen, for instance, may become metallic at core pressures (G. McCammon, A. Ringwood, and I. Jackson, 13th Lunar and Planetary Sciences Conference, Houston, 1982). The model density of at least the outer core is too low compared with pure iron (nickel added to iron raises, not lowers, its density at high pressures).

An iron–oxygen alloy, mostly of iron, could be a good fit to density models, but iron being liquid in the outer core would not necessarily constrain the solution of oxygen or certain other light elements to be metallic, according to Jeanloz. Molten iron at core pressures could dissolve all sorts of elements, compounds, and species, metallic and otherwise. The quantum spin state of iron and other transition elements are unknown or very poorly defined, even in theory, at core pressures.

Composition aside, models of the inner core are becoming better resolved and are exhibiting significant fine structure. Strong velocity gradients of seismic waves have been observed in the outer several hundred kilometers of the inner core, although the inner–outer core boundary appears to be narrowly defined, even sharp, for P-waves (H. Hage, *Physics of the Earth and Planetary Interiors, 31*, 171, 1983).

The result of the postulated inner–outer core model properties is that, for shear waves, the boundary would appear to rise or fall as a function of frequency. For high frequencies the outer portions of the inner core would behave differently than they would for lower frequencies. Anderson has suggested that a critical measurement of effective inner core radius to see whether it varies with frequency should be done. Until numerous factors about the behavior of materials under core conditions can be evaluated, however, the models will be non-unique.—*PMB*

TRAVEL TO IUGG GENERAL ASSEMBLY

AGU has arranged inexpensive group flights to the 18th General Assembly of the International Union of Geodesy and Geophysics August 15-27, 1983 Hamburg, West Germany. Departures have been booked on NORTHWEST ORIENT on August 13, or you may choose from a wide variety of other available flights. Group rates are available from most major American cities (from $619 round trip East Coast). For reservations and information, call PASSAGE TOURS

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IUGG Travel Grants

AGU has awarded $57,722 to 84 scientists as travel support for U.S. participation in the 18th General Assembly of the International Union of Geodesy and Geophysics (IUGG), to be held in Hamburg, F.R.G., August 15–27. The 84 awardees were selected from 276 applicants. Funding is for approximately 90% of the group air fares for which AGU contracted, through Passage Tours, with Northwest Orient Airlines. The National Science Foundation supplies the travel grant funds; AGU administers the grant process.

Scientists awarded the IUGG travel grant will attend symposia sponsored by the International Association of Geodesy (IAG), the International Association of Geomagnetism and Aeronomy (IAGA), the International Association of Hydrological Sciences (IAHS), the International Association of Meteorology and Atmospheric Physics (IAMAP), the International Association for the Physical Sciences of the Ocean (IAPSO), the International Association of Seismology and Physics of the Earth's Interior (IASPEI), and the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI). Those attending, as of May 2, are:

- IAG: Roger G. Bilham, Yehuda Bock, Rolland L. Hardy, Warren G. Heller, Richard H. Rapp, Narendra K. Saxena, Byron D. Tapley, Urho A. Uotila, and James H. Whitcomb.
- IAGA: Subir K. Banerjee, Charles E. Barton, Christopher G. A. Harrison, Thomas W. Hill, Kenneth A. Hoffman, Roberta M. Johnson, Robert H. Manka, Robert L. McPherron, Lawrence R. Megill, Christopher T. Russell, David J. Stevenson, David B. Stone, and Brian A. Tinsley.
- IAHS: Jaime Amorocho, Edmund D. Andrews, Robert Brakenridge, Nathan Buras, Raymond A. Ferrara, Dennis P. Lettenmaier, Helen J. Peters, Ramachandra A. Rao, Timothy D. Steele, Wendell V. Tanghorn, and Jennie C. Ting.
- IAMAP: Robert G. Ellingson, Inez Y. Fung, Catherine H. Gautier, David J. Hofmann, James L. Kinter, G. Wesley Lockwood, Julius London, John D. Mathews, Jan Paegle, Edward M. Patterson, Robert G. Roper, Gary J. Rottman, and Gunter Weller.
- IAPSO: Karen S. Baker, Richard T. Barber, Michael L. Bender, Melbourne G. Briscoe, Thomas M. Church, Margaret Louis Delaney, Patrick C. Gallacher, Thomas W. C. Hilde, A. Dennis Kirwan, Murray D. Levine, David R. Schink, Jonathan H. Sharp, Charles W. Van Atta, and Michael L. Van Woert.
- IASPEI: Thomas J. Ahrens, Kenneth C. Creager, Donald W. Forsyth, Bradford H. Hager, R. N. Hey, J. Casey Moore, Jack E. Oliver, Peter L. Olson, Gerald Schubert, Robert B. Smith, Lisa M. Stewart, and Lynn R. Sykes.
- IAVCEI: Keir Becker, Nikolas I. Christensen, Wolfgang E. Elston, Dennis E. Hayes, Jose J. Honnorez, Robert W. Kay, Juergen Kienle, Sathy A. Naidu, David W. Scholl, Stephen Self, Thomas J. Shankland, and Michael F. Sheridan.—*BTR*

Fulbright Update

Opportunities to teach or perform postdoctoral research in the earth and atmospheric sciences under the Senior Scholar Fulbright awards program for 1984–1985 (*Eos*, March 1, 1983, p. 81) are available in 14 countries, according to the Council for International Exchange of Scholars.

The countries and the specialization opportunities are Algeria, any specialization; Australia, mineral processing research; India, any specialization in geology or geophysics; Israel, environmental studies; Korea, any specialization; Lebanon, geophysics, geotectonics, and structural geology; Morocco, research methods in science education; Pakistan, geology, marine biology, and mineralogy; Poland, mining technology; Sudan, geology and remote sensing; Thailand, planning and environmental change; USSR, any specialization; Yugoslavia, any research specialization; and Zimbabwe, exploration geophysics and solid earth geophysics.

Deadlines for submission of applications are June 15, 1983, for work in Australia and September 15, 1983, for work in Africa, Asia, Europe, and the Middle East. For additional information, contact the Council for International Exchange of Scholars, 11 Dupont Circle, Suite 300, Washington, DC 20036 (telephone: 202-833-4985).

DELEGATES
18th General Assembly of IUGG

U.S. scientists planning to attend the 18th General Assembly of IUGG, Hamburg, West Germany, August 15–27, 1983, should notify A. F. Spilhaus, Jr., Secretary, U.S. National Committee, 2000 Florida Avenue, N.W., Washington, D.C. 20009, and indicate in which IUGG association they propose to participate so that they can be officially designated as delegates from the United States.

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Contents: IUGG Quadrennial Report
Planetology

Magnetospheric and Interplanetary Physics 1979 – 1982

David P. Stern
Planetary Magnetosphere Branch, Goddard Space Flight Center, Greenbelt, MD 20771

The quadrennium 1979–1982 witnessed notable advances in magnetospheric and interplanetary physics and demonstrated some major trends. Examples of both will be listed below, followed by an evaluation of the state of the discipline and of its future.

Standing out among the advances is the enormous volume of data about the magnetospheres of the giant planets collected by Voyagers 1–2 and by Pioneer 11. At the start of 1979 the very existence of Saturn's magnetic field was uncertain, and the role of the satellite Io in Jupiter's magnetosphere was only dimly guessed. Four years later we have extensive information on both magnetospheres, on their underlying planetary fields, ring currents, radio emissions, plasma composition, and nightside configuration, and about such matters as Io's plasma torus and the current filament linking Io to Jupiter, Saturn's inner radiation belt (from neutron albedo), and Titan's wake.

During the same interval great strides were also made toward tracing the behavior of different ion species in the earth's magnetosphere, charting the variability of different ions, and deducing their sources. The effort included widespread international collaboration, with key observations coming from European experiments. Much has been learned, but the data must still be extended to the 20–200 keV energy range, where most of the energy resides. Details have also come to light about the global distribution of 'beams' and 'conics,' and about the relative abundances of O+, He+, He++, H+ and O++. Further properties of field-aligned voltage drops have been noted, including a suggestion of very narrow electric field structures, observable only with a millisecond time resolution.

Substorms

Auroral kilometric radiation was observed by ISEE-1 (and more recently by DE-1) in its source region, and considerable theoretical effort has gone into explaining its origin. Theory has also greatly advanced in computer simulation of global MHD flow in the magnetosphere. On the other hand, there was only modest progress toward understanding the magnetic substorm, where interesting statistical analyses were conducted on the correlation between interplanetary parameters and substorm activity related to the role of magnetic energy storage in substorms. Better information about the thickness and motion of the magnetopause was provided by the combination of ISEE-1 and -2, and ISEE also provided new evidence for magnetic reconnection on the day side.

New phenomena which still have to be placed in proper context include 'flux transfer events' at the dayside boundary, collimated beams along the boundary of the plasma sheet, the 'theta aurora' observed in the polar cap by the optical imager of DE-1, and some interesting changes in magnetic and plasma patterns observed in synchronous orbit near midnight just prior to substorm onset.

While substorms continue to attract attention, serious studies were also devoted to the quiet state of the magnetosphere during times of 'northward' interplanetary magnetic polarity. Several studies have suggested that even at such times the crosspolar potential does not fall below a baseline of about 30 kV, and that on occasion its usual two-lobed configuration is replaced by a four-lobed one. There has also been interest in the contracted polar cap at such times and in polar cap auroral arcs.

In interplanetary physics the study of the earth's bow shock has benefitted greatly from the ISEE spacecraft constellation, which among other things has provided new data about the foreshock, about waves propagating upstream of the shock, and about the role such waves may play in particle acceleration. On a larger scale, heliospheric observations now range from 0.3 AU (Helios 1–2) to 28 AU (Pioneer 10), with Pioneer 11, Voyagers 1–2, and earth-based spacecraft at intermediate distances. During the quadrennium such data were combined with observations of coronal white light and of photospheric magnetic fields to yield definite results about the heliospheric current sheet and about the associated magnetic configuration around solar maximum.

New Instruments and Techniques

New instruments have meanwhile observed both the masses and the charge states of solar wind ions, noting both a high He+ component in the driver gas behind shocks and an anomalously low He abundance at sector boundaries. Other new developments involve the correlation of shocks and coronal transients, new theoretical work on the origin of the solar wind, and observations of a tail-wake extending several AU behind the magnetosphere of Jupiter.

Notable new techniques during the quadrennium include growing use of electron beam experiments, including one aboard the STS-3 mission of the space shuttle in March 1982 whose results are still mostly unpublished. An 'active' experiment injecting into the magnetosphere radio waves of about 3 kHz, from Siple Station in Antarctica, has yielded many interesting observations, and the 'Cameo' barium release from orbit demonstrated both a new way of generating ion jets and the existence of large correlated structures of $E_{\parallel}$. Other technical advances involved auroral radars and ionospheric modification. As these lines are being written, data analysis from the twin coplanar DE spacecraft is just beginning, and the ISEE-3 spacecraft has moved into the earth's distant magnetic tail, an important region about which only sparse information exists. These and other achievements are described more fully, with appropriate citations, in the 11 reports that follow.

Outlook

What about long-term trends? More and more, physicists are led to combine data from a network of widely separated spacecraft to study phenomena (e.g., substorms) which no single spacecraft can adequately observe. Our observing network may have reached a peak at the beginning of the quadrennium, around 1979: Never before has the magnetosphere seen such an impressive array of diverse spacecraft in different orbits—the 3 ISEEs, IMP 8, SCATHA, AE-5, GOES 2–3, plus international spacecraft such as ISIS 1–2 (Canada), Kyokko and Jikiken (Japan), GEOS 1–2 (ESA) and the Prognoz series (USSR), plus 'piggyback' scientific instruments aboard Triad, the DMSP series, ATS-6, and others. It was a fitting finale for the International Magnetospheric Study (IMS) [*Russell and Southwood*, 1982], and in view of the worldwide economic belt-tightening, this level of activity is not likely to be exceeded for some time.

If this great body of observations is to be used as a single, correlated data set, large computers, sophisticated programs, and wide-ranging cooperation are essential. The past quadrennium has shown that none of these are easily achieved. Coordinated Data Analysis Workshops (CDAWs) organized by the National Space Science Data Center in Greenbelt around selected, short (~24 h) time intervals [*Manka et al.*, 1982] have demonstrated the extent to which the data analysis task overshadows existing methods of data display and analysis and of modeling physical processes. Even two-spacecraft correlations between ISEE 1 and 2 have been far fewer than what was earlier envisioned.

Data Analysis

In coming years the schedule of new missions is likely to be rather modest, and this is regrettable: As scientific problems are better understood and more accurately defined, additional new missions, such as AMPTE, Galileo, and the proposed OPEN mission will be needed in order to shed new light on them. The magnetospheric science community, however, may well devote more of its time to analyzing the data backlog 'awaiting disclosure in data freight yards and tape libraries' [*Greenstadt and Fredricks*, 1979, sec. 7]. On no account should any part of this data set be discarded or allowed to become unusable until that analysis is completed.

The problem has several aspects. The sheer volume of data requires extensive memory and computing power, such as only now are becoming available. Furthermore, data networks, summary plot information and data-handling software must be developed [*Smith et al.*, 1981]. Beyond that, however, ways must also be found for using those new tools efficiently. For instance, existing models of the magnetospheric B are still not far removed from those devised by Gauss, while the stacked plots and many-colored spectrograms so often encountered in the literature testify that no one has yet devised a concise method for handling multidimensional data. It sometimes seems that the resources of the magnetospheric science community are stretched thin by the great data-handling demands. Thus, even though the importance of AE indices is generally acknowledged, such indices have been compiled only for part of the quadrennium.

Beyond this, a great need exists for consolidating past gains of magnetospheric and interplanetary physics. This year marks the 25th anniversary of the IGY, when the first artificial satellites were launched and the study of space physics jumped to its present high level. In those early days it was easy for newcomers to assimilate much of what was known and to advance to the forefront of research, and useful experiments could be built with only modest resources. Today's instruments and data systems are quite sophisticated, and the amount of scientific work being published swamps those who hope to keep up with it. To help newcomers (and perhaps also oldtimers who try to keep head above water!), texts, reviews, and courses are needed, especially in the theory, which now must be pieced together from numerous journal articles. Thus a recent theory institute [*Carovillano and Forbes*, 1983] should be viewed as a welcome step, and it is hoped that the following reports will also help fill those needs.

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Contents: IUGG Quadrennial Report
Solar–Planetary Relationships: Magnetospheric Physics

News

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Questions are frequently raised about programs beyond the year 2000. More pertinent are questions about plans between now and then. The National Aeronautics and Space Administration's (NASA) Advisory Council Solar System Exploration Committee (SSEC) has attempted to answer some of these questions in its 1983 report on *Planetary Exploration Through Year 2000*. The report attempts to identify 'the essential attitudes of a viable program in planetary sciences' and to define 'new ways to reduce costs.'

The reasons for this approach are painfully obvious. The Venus Radar Mapper mission (VRM) instigated this year is the first new start that NASA has had authorized in years. Space missions with the sort of achievement record of the 'Golden Age' traditionally require long lead times. Without a new approach the U.S. space exploration program will soon be at an end. Beginning with the VRM, which is being fabricated from spare and used spacecraft parts, a series of new, efficiently planned missions is being formulated to constitute a modestly scaled but high-scientific-yield program. The SSEC has successfully provided a route to achieve the highest priority goals of a viable scientific space exploration through 2000.

The plan is based on extending knowledge of the solar system, knowledge which has been so richly expanded during the past two decades. The 'Core Program' includes the VRM, whose mission is to continue mapping unexplored regions of the surface of Venus, and the Mars Geoscience/Climatology Orbiter to determine the surface composition of Mars and thereby obtain global classification of the two most earth-like planetary bodies in the solar system. Also included in the Core Program are the Comet Rendezvous and Asteroid Flyby and the Titan (largest moon of Saturn) Probe/Radar Mapper. The schedule of these missions is as follows:

Mission	Launch	Data Return
Venus Radar Mapper	1988	1988–89
Mars Geoscience/Climatology Orbiter	1990	1990–92
Comet Rendezvous/Asteroid Flyby	1990–92	1994–2000
Titan Probe/Radar Mapper	1988–92	1995–97

Following the core program of four missions, subsequent missions to the inner planets, to small bodies, and to the outer planets, are planned as follows:

The Mars Aeronomy Orbiter will investigate the interaction of the planet's upper atmosphere and ionosphere with radiation and particles of the solar wind.

The Venus Atmospheric Probe will provide definitive information on the abundance of major and minor trace components of the Venus atmosphere toward an understanding of conditions in the intersolar system at the time the planets accreted.

The Lunar Geoscience Orbiter will provide a global map of surface elemental and mineralogical composition, and other properties, and decide the question of the presence of condensed water and other volatiles in polar cold traps.

The Mars Surface Probe mission will establish seismic, meteorological, and geoscience stations on the Martian surface. These will determine the level of Martian seismicity, provide surface weather data toward an understanding of its climatic pattern, and will also provide detailed geochemical analyses.

The Comet Atomized Sample Return mission will provide a detailed elemental and isotopic composition analysis of gases and dust from the coma of a comet, data complementary to that acquired by a Comet Rendezvous mission. Ideally, the material will be returned to terrestrial laboratories from the same comet observed by the rendezvous spacecraft.

The Multiple Mainbelt Asteroid Orbiter/Flyby mission will initiate the exploration of the asteroids by providing a detailed characterization of at least one such body while at the same time sampling the diversity of chemical and physical types.

The Earth-approaching Asteroid Rendezvous mission will characterize in detail a selected member of this class of bodies.

The Saturn Orbiter will address goals related to the characterization of the Saturnian satellites, ring systems and magnetosphere. It will provide the first time resolution of ring structures, close approaches to poorly seen satellites, and additional radar coverage of Titan's surface.

The Saturn and the Uranus Flyby Probe missions will provide in situ determination of the composition and structure of the Saturnian and Uranian atmospheres and clouds for comparison with the Jovian case as determined by the Galileo probe.

The extensive anticipated accomplishments are exciting, perhaps awesome. Global mapping of the moon's surface may lead to a better understanding of its origin, and of the earth's—there will be a search for lunar solar reservoirs of water ice. First visits will be made to near-earth and mainbelt asteroids. Direct analyses will be made of Titan's atmospheric composition and structure; the results will provide insights to the prebiotic state of the earth's surface. Exploration of the atmosphere and surface of Venus, earth's sister planet, may lead to an understanding of the state of its geological development. The list of scientific goals goes on; explorations of Saturn, Jupiter, and of Uranus are on that list.—*PMB*

Coalinga Quakes

A magnitude 6.5 (Richter scale) earthquake hit the city of Coalinga, Calif., about 520 km southeast of San Francisco, at 4:42 p.m. (PDT) on May 2. The earthquake, the largest to strike the region in at least 100 years, occurred on the extreme eastern edge of the 105-km-wide zone of active faults that form the San Andreas system in central California, according to the U. S. Geological Survey (USGS). More than 1,500 aftershocks, including two that struck May 8 and registered magnitude 5.5, have continued to jolt the area.

No deaths were reported, but injuries exceed 45, according to James Brady of the U.S. Disaster Field Office in Coalinga. Damage, estimated at more than $30 million, has resulted in the displacement of more than 1,000 persons.

USGS scientists said that the fault responsible for the earthquake is of a different variety than the well-known San Andreas fault that is located 32 km west of Coalinga. The San Andreas is a major vertical fault along which most large earthquakes occur when there is a horizontal strike-slip movement, the USGS says. In contrast, the May 2 earthquake appears to have been generated on an ancient, buried coast range thrust fault that once separated the North American continent from the Pacific basin. Thrust fault movement causes one block to move over the other. The coast range thrust fault is tens of millions of years older than the San Andreas fault, according to USGS scientists.

Locations of the aftershocks indicate that movement along the coast range fault occurred over an elliptical zone that measures about 52 km x 9.7 km and is centered around the main shock. The focal point of most of the aftershocks is below 10.8 km in depth. Although the San Andreas fault was not directly involved in the Coalinga earthquake, readings from sensitive fault displacement meters along the San Andreas in the Parkfield, Calif., area indicate a displacement of 0.5 cm.

Discovery of the thrust fault, a previously unknown type in the area, leads scientists to believe that other buried faults exist in the region, according to a USGS spokesman. Locating such faults will be difficult because no ruptures appear at the surface. The magnitude of the May 2 quake and the reactivation of the ancient fault imply that the period of quiescence is over and that a period of larger earthquakes has begun, the spokesman said. Leonardo Seeber of the Lamont-Doherty Geological Observatory said that the increase in seismic activity in the area began about 1979.

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Cover. Major tectonic and morphologic elements in the western South American subduction zone. The seismic lines are labeled according to 1976 profiles. > symbols due west off Callao indicate ASPER stations; CDP: common-depth-point digital seismic line. A–P: Abancay–Pisco deflection; H–P: Huancabamba–Paita deflection. Note that the active volcanoes (solid triangles) are outside of the segment bounded by the two deflections. Illustration from 'Geophysical Data and the Nazca–South American Subduction Zone Kinematics: Peru–North Chile Segment,' by L. Ocola, in *Geodynamics of the Eastern Pacific Region, Caribbean and Scotia Arcs, Geodynamics Series*, vol. 9, edited by R. Cabré. Published by AGU. For more details on this new AGU volume, see the 'Books' section, p. 388.

Core Models

Newly formulated models of the earth's core have been described recently as 'simultaneously provocative and vexing' (R. Jeanloz, *Nature, 299*, 108, 1982). Part of the reason for this is that concepts about the earth's core are being rapidly updated.

That there is knowledge at all of a core results from the analysis of seismic data; such analysis is model-dependent. Further analysis of more extensive data results in new models; alternative approaches to the problems from theoretical geochemical considerations result in another type of model. The conjunction of such models may seem incongruous, but not so. A great deal is being learned about the geochemistry of processes that have a bearing on core formation. Significantly, there has been a simultaneous surge of improved seismic data and analysis.

The results are intriguing. Whatever geophysicists may have thought about the earth's core, its boundary with the mantle, its molten outer and solid inner sections, and the boundary between them, and even its composition, today's models are proving there are differences. Recent sheer wave data have brought into question the nature of the core–mantle boundary. The new models do not allow for even a thermal layer (T. Lay and D. V. Helmberger, *Geophysical Research Letters, 10*, 63, 1983). Either the boundary is diffuse or there is a distinct layer, neither mantle nor core, where a distinct boundary had been thought to occur.

The outer core data still fits fluid model concepts; however, concepts of the inner core and the outer boundary are being changed. One possibility is that the depth to the boundary may be variable depending on the properties of seismic waves that are used to 'interrogate.' The inner core material may be in a conceptually new state such that the inner core may have the properties somewhere between those of a solid and a fluid (D. L. Anderson, *Nature*, April 1983).

The general concept of the earth's core is that it is mostly fluid, the inner-solid portion having diameter of about 1215 km. The old idea that the core is a iron–nickel alloy, like iron meteorites, has long since been dispensed with on experimental grounds; but that the composition is an iron alloy is still current.

One difficulty has been that core models have been constructed by attempting to fit one-atmosphere iron and iron-alloy data to seismic models. The appropriate properties of materials under conditions of the earth's core—(1.5–3.5 Mbar, greater than 3000°C) have never been determined. 'Very good' shockwave data on iron and iron melt are still uncertain by at least 1000°C (O. L. Anderson, *Philosophical Transactions of the Royal Society of London, A306*, 21, 1982).

Part of the interpretation problem results from iron and its melt being almost indistinguishable in a shockwave experiment. The category of properties that could render iron to appear as fluid or solid in shear strength terms, that is, depending on the frequency of a seismic wave, could indeed characterize the outer parts of the inner core.

A new twist on modeling the core's composition is that certain light elements, oxygen, for instance, may become metallic at core pressures (C. McCammon, A. Ringwood, and J. Jackson, 13th Lunar and Planetary Sciences Conference, Houston, 1982). The model density of at least the outer core is too low compared with pure iron (nickel added to iron raises, not lowers, its density at high pressures).

An iron–oxygen alloy, mostly of iron, could be a good fit to density models, but iron being liquid in the outer core would not necessarily constrain the solution of oxygen or certain other light elements to be metallic, according to Jeanloz. Molten iron at core pressures could dissolve all sorts of elements, compounds, and species, metallic and otherwise. The quantum spin state of iron and other transition elements are unknown or very poorly defined, even in theory, at core pressures.

Composition aside, models of the inner core are becoming better resolved and are exhibiting significant fine structure. Strong velocity gradients of seismic waves have been observed in the outer several hundred kilometers of the inner core, although the inner–outer core boundary appears to be narrowly defined, even sharp, for P-waves (H. Hage, *Physics of the Earth and Planetary Interiors, 31*, 171, 1983).

The result of the postulated inner–outer core model properties is that, for shear waves, the boundary would appear to rise or fall as a function of frequency. For high frequencies the outer portions of the inner core would behave differently than they would for lower frequencies. Anderson has suggested that a critical measurement of effective inner core radius to see whether it varies with frequency should be done. Until numerous factors about the behavior of materials under core conditions can be evaluated, however, the models will be non-unique.—*PMB*

IUGG Travel Grants

AGU has awarded $57,722 to 84 scientists as travel support for U.S. participation in the 18th General Assembly of the International Union of Geodesy and Geophysics (IUGG), to be held in Hamburg, F.R.G., August 15–27. The 84 awardees were selected from 276 applicants. Funding is for approximately 90% of the group air fares for which AGU contracted, through Passage Tours, with Northwest Orient Airlines. The National Science Foundation supplies the travel grant funds; AGU administers the grant process.

Scientists awarded the IUGG travel grant will attend symposia sponsored by the International Association of Geodesy (IAG), the International Association of Geomagnetism and Aeronomy (IAGA), the International Association of Hydrological Sciences (IAHS), the International Association of Meteorology and Atmospheric Physics (IAMAP), the International Association for the Physical Sciences of the Ocean (IAPSO), the International Association of Seismology and Physics of the Earth's Interior (IASPEI), and the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI). Those attending, as of May 2, are:

- IAG: Roger G. Bilham, Yehuda Bock, Rolland L. Hardy, Warren G. Heller, Richard H. Rapp, Narendra K. Saxena, Byron D. Tapley, Urho A. Uotila, and James H. Whitcomb.
- IAGA: Subir K. Banerjee, Charles E. Barton, Christopher G. A. Harrison, Thomas W. Hill, Kenneth A. Hoffman, Roberta M. Johnson, Robert H. Manka, Robert L. McPherron, Lawrence R. Megill, Christopher T. Russell, David J. Stevenson, David B. Stone, and Brian A. Tinsley.
- IAHS: Jaime Amorocho, Edmund D. Andrews, Robert Brakenridge, Nathan Buras, Raymond A. Ferrara, Dennis P. Lettenmaier, Helen J. Peters, Ramachandra A. Rao, Timothy D. Steele, Wendell V. Tangborn, and Jennie C. Ting.
- IAMAP: Robert G. Ellingson, Inez Y. Fung, Catherine H. Gautier, David J. Hofmann, James L. Kinter, G. Wesley Lockwood, Julius London, John D. Mathews, Jan Paegle, Edward M. Patterson, Robert G. Roper, Gary J. Rottman, and Gunter Weller.
- IAPSO: Karen S. Baker, Richard T. Barber, Michael L. Bender, Melbourne G. Briscoe, Thomas M. Church, Margaret Louis Delaney, Patrick C. Gallacher, Thomas W. C. Hilde, A. Dennis Kirwan, Murray D. Levine, David R. Schink, Jonathan H. Sharp, Charles W. Van Atta, and Michael L. Van Woert.
- IASPEI: Thomas J. Ahrens, Kenneth C. Creager, Donald W. Forsyth, Bradford H. Hager, R. N. Hey, J. Casey Moore, Jack E. Oliver, Peter L. Olson, Gerald Schubert, Robert B. Smith, Lisa M. Stewart, and Lynn R. Sykes.
- IAVCEI: Ken Becker, Nikolas I. Christensen, Wolfgang E. Elston, Dennis E. Hayes, Jose J. Honnorez, Robert W. Kay, Juergen Kienle, Sathy A. Naidu, David W. Scholl, Stephen Self, Thomas J. Shankland, and Michael F. Sheridan.—*BTR*

TRAVEL TO IUGG GENERAL ASSEMBLY

AGU has arranged inexpensive group flights to the 18th General Assembly of the International Union of Geodesy and Geophysics August 15-27, 1983 Hamburg, West Germany. Departures have been booked on NORTHWEST ORIENT on August 13, or you may choose from a wide variety of other available flights. Group rates are available from most major American cities (from $619 round trip East Coast). For reservations and information, call

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Fulbright Update

Opportunities to teach or perform postdoctoral research in the earth and atmospheric sciences under the Senior Scholar Fulbright awards program for 1984–1985 (*Eos*, March 1, 1983, p. 81) are available in 14 countries, according to the Council for International Exchange of Scholars.

The countries and the specialization opportunities are Algeria, any specialization; Australia, mineral processing research; India, any specialization in geology or geophysics; Israel, environmental studies; Korea, any specialization; Lebanon, geophysics, geotectonics, and structural geology; Morocco, research methods in science education; Pakistan, geology, marine biology, and mineralogy; Poland, mining technology; Sudan, geology and remote sensing; Thailand, planning and environmental change; USSR, any specialization; Yugoslavia, any research specialization; and Zimbabwe, exploration geophysics and solid earth geophysics.

Deadlines for submission of applications are June 15, 1983, for work in Australia and September 15, 1983, for work in Africa, Asia, Europe, and the Middle East. For additional information, contact the Council for International Exchange of Scholars, 11 Dupont Circle, Suite 300, Washington, DC 20036 (telephone: 202-833-4985).

DELEGATES
18th General Assembly of IUGG

U.S. scientists planning to attend the 18th General Assembly of IUGG, Hamburg, West Germany, August 15–27, 1983, should notify A. F. Spilhaus, Jr., Secretary, U.S. National Committee, 2000 Florida Avenue, N.W., Washington, D.C. 20009, and indicate in which IUGG association they propose to participate so that they can be officially designated as delegates from the United States.

Books

AGU New Books

Geodynamics of the Eastern Pacific Region, Caribbean and Scotia Arcs

Geodynamics Series, vol. 9, Ramón Cabré, S. J. (Ed.), 176 pp., illustrated, 1983, AGU members: $16.80; institutions, $24.00.

Geodynamic phenomena related to the interaction of the eastern Pacific with the Americas between Canada and the Antarctic peninsula are examined in this volume, which presents the final report of Working Group 2 of the International Geodynamics Program of the Inter-Union Commission on Geodynamics. The discussions include the following topics:

- Changes in the spreading rate and the character of the Juan de Fuca Ridge and its associated small, complex plate
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- The two geological provinces of the Scotia arc: that of the Pacific margin, which began its development as early as the Paleozoic; and that coinciding with the Scotia Sea, developed as a complication of the South American-Antarctic plate boundary over the past 40 m.y.

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Ramón Cabré, Editor

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Hydrologist/Environmental Scientist. Ph.D. research associate seeks research/teaching position. Research areas include soil water dynamics, watershed modeling, hillslope hydrology, contaminant transport. Interested also in climatology and ecology. Would consider also a nonacademic job. Box 018, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

POSITIONS AVAILABLE

University of Georgia/Faculty Positions. The Department of Geology anticipates hiring as many as five people at the rank of Assistant or Associate Professor, on either a permanent (tenure track) or temporary basis.

Duties include teaching undergraduate and graduate courses and conducting research.

Teaching/research specializations to be considered include: economic geology, geochemistry, mineralogy/petrology, paleontology, sedimentation, structural geology, geophysics, and marine geology.

Letter of application—including a statement of specific teaching and research interests, curriculum vita, and names and addresses of three references—should be sent to: Head
Department of Geology
University of Georgia
Athens, GA 30602.

Deadline for receipt of applications is June 20, 1983. Should sufficient candidates not be found, another search may be opened.

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Structural Geology/Petrology. Lafayette College seeks a person to teach undergraduate physical and structural geology, igneous and metamorphic petrology, and additional courses, dependent on applicant's interests. Ability to teach introductory geophysics is desirable but not mandatory. Teaching load averages ten to twelve contact hours and two courses/semester. Appointment as assistant professor (Ph.D. complete) or instructor (Ph.D. pending).

Send application and resume, and arrange for three reference letters to Dr. Richard W. Faas, Department of Geology, Lafayette College, Easton, PA 18042.

Lafayette College is an equal opportunity employer. M/F. Women and minorities are encouraged to apply.

Faculty Position in Sedimentary Geology at the University of South Carolina. Applications are invited for a tenured track faculty position in the Department of Geology with a specialization in sedimentology starting as early as August 1983.

Ph.D. required. Rank and salary are open depending on qualifications and experience. We seek a candidate whose research interests are in one or more of the following fields: carbonate depositial systems, basin analysis, global sediment cycling, stratigraphy and sedimentary geochemistry.

The successful candidate is expected to develop a strong research program with external funding, supervise graduate students, and teach graduate and undergraduate courses. Send letter of application, vitae, statement of research interests, and names of three references to: Dr. Robert C. Thunell, Department of Geology, University of South Carolina, Columbia, SC 29208.

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Research Assistantships for Studies in Air Pollution and Atmospheric Chemistry/Washington State University. For MS or Ph.D. in Engineering or Environmental Science. Graduate degree programs can also lead to specific degrees in Chemical Engineering, Mechanical Engineering, or Environmental Engineering. Individual programs can be designed to fit student background, special interests, and experience.

Current research programs include: Antarctic studies (including field and winterover programs), pollutant transport, tracer studies, complex terrain modeling, biogenic emissions, global atmospheric chemistry, and atmospheric monitoring.

Candidates are sought with BS in meteorology (or equivalent), chemistry, physics or engineering. Stipend is $6,900/nine month; $11,500/twelve in some cases. Tuition assistance available to suitable candidates. September 1983 and February 1984 enrollments available.

Contact E. Robinson, Air Pollution Program, 306 Dana Hall, Washington State University, Pullman, Washington 99164–2730 or telephone collect for further information 509-335-1526.
EO/AAE.

GFD Position/Texas A&M University. The Department of Oceanography of Texas A&M University has an opening for a tenure track assistant professor in physical oceanography to be filled by 1 September 1983.

Preference will be given to candidates with strong theoretical background in geophysical fluid dynamics.

The successful applicant will be expected to teach undergraduate and graduate courses and to conduct a vigorous research program in his or her specialty. A Ph.D. is required for the position and one year's experience in a postdoctoral position is desired. Salary is negotiable depending upon experience and qualifications.

Applicant should submit a vita along with a letter describing his/her research and teaching goals and names of five persons for reference to Professor R.O. Reid, Head, Department of Oceanography, Texas A&M University, College Station, TX 77843. The closing date for applications is May 31, 1983. Texas A&M University is an affirmative action equal opportunity employer.

Research Associate. The Stanford University School of Earth Sciences and the Center for Materials Research seek research-oriented scientist for an initial three-year appointment to start approximately October 1 1983 whose responsibilities will include (1) Supervision and maintenance of a new XRF XRD facility (2) Supervision of a new ESCA spectrometer, and (3) interaction with our microprobe technician in optimizing software for geological applications. Duties will include training faculty and student users of the XRF, XRD, and ESCA, but not service work. Experience in operation of XRF, XRD, and/or electron microprobe required; we will train on the ESCA. A good working knowledge of DEC Series 11 computers (11/02, 11/23, 11/34) operating under the RSX-11M monitor and of FORTRAN level programming is essential. Although we envision that the duties associated with this new equipment will constitute a full-time job for a year or two, we prefer Ph.D.-level applicants who desire eventually to develop their own research program in conjunction with Stanford geology faculty.

Send C.V. to Gail Mahood, Department of Geology, Stanford University, Stanford, CA 94305. Stanford University is an equal opportunity/affirmative action employer.

University of Colorado, Boulder, Geochemist Position. Geochemist with active research program, stable isotopes, radioactive isotopes, and/or trace elements is being sought for a joint appointment in the Department of Geological Sciences and the Cooperative Institute for Research in Environmental Sciences (CIRES) of the University of Colorado. The one-half time position within the Department of Geological Sciences is tenure-track at the assistant or associate professor level with a starting salary of $12,000–$15,000 for the academic year. Teaching load will be half that of full-time faculty. The position within CIRES will be as a Fellow with appropriate office and laboratory space. One-half academic year salary will be guaranteed by CIRES for the second half-year at the departmental rate, after which incumbent must generate his/her CIRES salary from external sources. Incumbent may augment salary by generating three months of summer salary from contracts and grants, and consulting.

Applicants with experience, publications, and/or movable existing research equipment preferred. Preferred starting date would be January 1, 1984. Closing date for applications is October 1, 1983.

Applications should include statement of research and teaching interests, experience, a full vitae, and four letters of reference.

Apply to: Professor Charles Stern, Chairman, Geochemist Search Committee, Department of Geological Sciences, Campus Box 250, University of Colorado, Boulder, CO 80309.

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The successful candidate(s) will join our experimental research programs in solar terrestrial physics and planetary atmospheres. LASP has ongoing sounding rocket and satellite programs dedicated to the development of state-of-the-art instruments for space research.

An advanced degree is required; a background in solar, planetary or atmospheric sciences is desirable although experience in related areas will be considered. Salary commensurate with experience.

Applications, including a current professional resume and the names of three references should be sent by June 10, 1983, to:
Dr. Charles A. Barth, Director
Laboratory for Atmospheric and Space Physics
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University of Colorado
Boulder, CO 80309.

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Research Positions for Mathematical Physicists. Applications are invited for several research positions at the Center for Studies of Nonlinear Dynamics, La Jolla Institute, beginning summer 1983. Current research involves work on nonlinear wave-wave interactions, acoustic, optical, and radio wave propagation in random media, and fluctuation phenomena in the statistical mechanics of chemical and geophysical systems. Physicists and applied mathematicians who are interested in working on problems of the above type should send resumes and arrange for three letters of recommendation to be sent to Dr. Stanley Flatte, Director, CSND, La Jolla Institute, 8950 Villa La Jolla Drive, Suite 2150, La Jolla, California 92037.

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Research Faculty Position in Space Physics/Boston University. The Astronomy Department at Boston University expects to have a research faculty position available for the 1983/84 academic year.

Applicants are sought who have a proven research record as evidenced by publications and recommendations and who have an interest in teaching at the graduate and undergraduate level. Applicants with research programs in any area of space physics will be considered; however, preference will be given to those with interests in ionospheric or magnetospheric space plasma physics. Rank will depend on qualifications and experience.

Applicants are particularly sought who can bring partial salary support. Teaching duties are based on the proportion of salary supported by departmental funds.

Please send a curriculum vitae, names of three persons who can provide an evaluation of your teaching and research and a brief statement of current research interests to:
Kenneth Janes, Chairman
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Seismologist. Lamont-Doherty Geological Observatory of Columbia University [illegible]

Physical Oceanography University of Rhode Island. [illegible]

Structural Geologist-Tectonophysicist. [illegible]

Assistant Professor/Crustal Reflection Seismology University of Wyoming. [illegible]

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Assistant Professor/Instructor in Meteorology. September 1, 1983. Department of the Earth Sciences has position primarily concerned with the teaching of the synoptic meteorology aspect (Synoptic Meteorology, Weather Forecasting Laboratory) of the undergraduate Meteorology Major program. The successful applicant should also be capable of teaching two or more courses in air pollution meteorology, advanced forecasting techniques, and computer applications. Will also assume the directorship of the College Weather Center. An earned doctorate in Meteorology or allied field preferred, with strong background in synoptic meteorology and computer applications. Experience in weather forecasting and teaching desirable.

A letter of application, resume, and three letters directly from references should be sent to: Office of Faculty and Staff Relations, 4th Floor Administration Building, State University College, Brockport, NY 14420. Closing date for receipt of applications: July 10, 1983.

State University of New York College at Brockport is an Equal Opportunity/Affirmative Action Employer.

Howard University/Graduate Faculty Position. The Department of Geology/Geography invites applications for a tenure-track position in geochemistry at rank of assistant or associate professor beginning August 1983. Position involves development of graduate research program at Master's level. Desired specialization includes environmental geochemistry, geochronology, isotope geology. Send letter of application, resume and names of three references to Dr. David Schwartzman, Department of Geology/Geography, Howard University, D.C. 20059.

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National Museum of Natural History/Smithsonian Institution. The Department of Mineral Sciences seeks applicants for two tenure track research positions on our professional staff in mineralogy, petrology, geochemistry, or meteoritics. Although primarily research oriented, the jobs will also include some involvement with other important museum functions, most notably collections curation and/or public education, particularly exhibits. A Ph.D. and broad interests in the geosciences are preferred. Appointments will be made at the GS-11 level ($24,508). One position available immediately, one position available after January 1, 1984 (with some flexibility in both starting dates). Closing date for applications is July 29, 1983.

The Department's collections of minerals, rocks, meteorites, and tektites are among the largest and finest in the world. The Department is well-equipped with modern analytical instruments including an automated electron microprobe. Close working relationships with other parts of Washington's extensive geologic community further extend the available facilities and expertise.

Applicants should send a resume (including a statement of research interests), the names of three references and a completed SF-171 form (or a request for said form) to: Office of Personnel Administration (MS), ATTN: Room 1413 A&I, Smithsonian Institution, Washington, DC 20560.

The Smithsonian Institution is an equal opportunity/affirmative action employer.

Director/ Geophysical Fluid Dynamics Laboratory: The Environmental Research Laboratories, NOAA. The U.S. Department of Commerce in Princeton, New Jersey, is seeking applicants for a scientific manager to serve as Director, Geophysical Fluid Dynamics Laboratory. The Director conceives, implements, and evaluates research programs to expand the scientific understanding of those physical processes which govern the behavior of the atmosphere and the oceans as complex fluid systems. This involves extensive inter- and intra-agency coordination as well as the direction of a 100-member staff engaged in research activities. Position is Career Reserved in the Senior Executive Service. Salary range: $56,945 to $67,200 per annum—negotiable based on experience, scientific achievement, and technical/managerial qualifications.

QUALIFICATIONS: Knowledge of theory and state of the art in a combination of disciplines (meteorology, oceanography, hydrology, classical physics, fluid dynamics, chemistry, and applied mathematics) to design, direct, and evaluate interdisciplinary research programs. Competence in the scientific management of theoretical and experimental research studies of a large-scale nature. Personal research in meteorology or oceanography. Executive competence in broad areas of administration such as program planning and evaluation, multigroup coordination, resource acquisition and administration, organizational representation, and human resource utilization including EEO.

TO APPLY: Interested persons should contact Ms. Barbara J. Peterson, NOAA/ERL, Personnel Services Division (R/E562), 325 Broadway, Boulder, CO 80303 (303) 497-5780 or FTS 320-5780 for application forms. Reference Vacancy #NOAA/ERL 82–269. Position announcement closes July 8, 1983.

AN EQUAL OPPORTUNITY EMPLOYER.

Chairman—Department of Geological Sciences, Wright State University. The Department of Geological Sciences, invites applications for the position of chairman, to be appointed September 1984. We seek a dynamic individual with administrative talent and an appreciation for research and practice-related educational activities. Rank is at the full professor level and no restrictions have been placed on areas of specialization. The department is active with 12 faculty and an emphasis on professional practice, yet maintaining a firm commitment to basic research.

Send a letter of application, curriculum vitae and names of three references to:
Chairman, Search Committee
Department of Geological Sciences
Wright State University
Dayton, OH 45435.

Wright State University is an affirmative action/equal opportunity employer. Closing date for the position is October 31, 1983.

STUDENT OPPORTUNITIES

Graduate Assistantships/Howard University. Howard University in Washington, D.C., offers a new graduate program for the M.S. degree in geoscience; made possible by a grant from the Gulf Oil Company. Areas of specialization are field geology/geophysics, geochemistry, and meteorology/hydrology with remote sensing. Some stipends and assistantships are available. Potential students should write to Dr. Eric Christofferson, Department of Geology and Geography, Howard University, Washington, D.C. 20059.

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Nonlinear Analysis, Inc.
1910 S. Highway 6, Suite 3C
Houston, Texas 77077
(713) 493-3287.

Penrose Conference on the Evolution of the Central Atlantic Ocean and Its Continental Margins. A Penrose Conference, "The West-African Connection—Evolution of the Central Atlantic Ocean and its Continental Margins" will convene January 16–21, 1984 at Glens, on the Mediterranean coast of France. To keep the cost to participants down, it will be held not in a resort hotel but in a simple, comfortable vacation village for families, on the shore 6 km from Toulon airport (two flights a day to Paris).

The goal of the conference is to bring together specialists with new geological and geophysical data on the history of the West-African connection. As the subject is large and the scope extensive, the conveners must insist on synthesis in each domain, even if it seems premature, so that the interrelations of the different problems can be discussed at length.

Those wishing to participate or to obtain more details should write to Professor J. Sougy at the address below by June 15, 1983, explaining what their contributions to the subject of the conference would be. Conveners: Professor J. Sougy, Laboratoire de Geologie dynamique, LA CNRS no. 132, Faculte des Sciences de Saint Jerome, 13307, Marseille Cedex 13, France (telephone (91) 98 90 10, ext. 510). Professor X. LePechon, Laboratoire de Geodynamique, Universite P. et M. Curie, 4 place Jussieu, 75230 Paris Cedex 05, France. Professor John Rodgers, Department of Geology and Geophysics, Yale University, P.O. Box 6666, New Haven, CT 06511.

Hydraulics and Transport of Pollutants in Groundwater/University of California, Irvine. State-of-the-art technology relating to groundwater pollution analysis will be presented in 'Hydraulics and Transport of Pollutants in Groundwater,' a five-day short course offered through University of California, Irvine Extension Monday-Friday, July 25–29, 1983. Specifically, the course will cover fundamental principles of groundwater flow and pollution transport in the zone of aeration and zone of saturation. Geochemical processes and the determination of transport parameters will be presented. The sources and control of pollutants and their long-term effects on aquifers will be evaluated. The course includes case histories and modern mathematical modeling and computer simulation techniques. The faculty includes Professor Jacob Bear, Albert and Ann Mansfield Chair in Water Resources at Technion, Haifa, Israel; Yoram J. Litwin, President of RAMLIT Associates, Berkeley, California and faculty member in the Hydraulics and Sanitary Division of UC Berkeley; T.V. Hromadka II, Hydrologist, Water Resources Division, U.S. Geological Survey; and Gary L. Guymon, Professor of Civil Engineering, UC Irvine. Course fee is $750 and includes course materials, lunches, one dinner and parking. For more information, contact UC Irvine Extension, P.O. Box AZ, Irvine, CA 92716; 714-833-5414.

AGU

Committees: The Backbone of AGU

Committees are the backbone of AGU; they serve in a variety of indispensable roles. They serve as consultants to the Council and as sources of ideas; they also provide continuing guidance to the staff. Committees review ongoing and proposed programs and suggest new ones. Reports presented to the Council for decisions on programs usually include an integration of staff and committee information. Committees may also act as operating extensions of staff capabilities, especially in cases where staffing is not financially feasible. AGU could not operate effectively without the strong core of volunteer help that participates in committee activities and on the Council. This participation provides the spirit that in turn serves as the example that allows any voluntary association to draw further vitality from its community.

Organization

The membership elects the Council, which consists of the president, president-elect, general secretary, foreign secretary, and the president and president-elect of each of the sections; the executive director, who is a member of the Council without vote, is appointed by the Council. The president is responsible for the appointment of all committees and of journal editors. The executive director is responsible to the Council for carrying out the programs of the Union as approved by the Council. The general secretary provides direction as to the intent of Council and monitors the headquarters operation on behalf of the Council.

Terms of Officers, Committee Chairmen, and Committee Members

All officers of the Union and its sections are elected to a 2-year term, beginning on July 1 of each even year and extending through June 30 of the next succeeding even year, except the foreign secretary and the general secretary, who are elected to 4-year terms. Each individual elected to the position of president-elect of a section or of the Union serves a 2-year term as president-elect and then a 2-year term as president. During both periods, he is a voting member of the Council of the Union, assuring considerable continuity and, hence, stability in Union affairs.

The terms of committee chairmen and committee members who are appointed by the president of the Union generally coincide with the term of that president.

Meetings of the Council and Committees

The AGU Council usually meets twice a year, at the Spring and Fall meetings of the Union. The Council sessions are scheduled to minimize conflicts with scientific sessions. Prior to each meeting, an annotated agenda is prepared that includes reports from the officers and committee chairmen who feel that they have something they want to bring to the attention of the Council. Each committee chairman is expected to report in writing at least once per year. The Council operates in a decision-making mode, with all areas to be discussed framed around questions. These questions are usually put to it by a committee and are accompanied by background documentation.

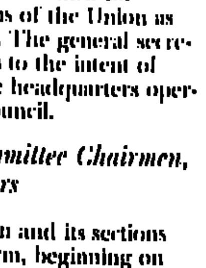
Council meetings are open. All voting members are expected to attend; in addition, committee chairmen, past-presidents, editors, and representatives to and from other associations are invited, and other members of the Union are welcome.

The Union does not pay transportation expenses or per diem for Council members or for committee members to attend meetings held in conjunction with the Fall and Spring meetings. It is anticipated that these individuals will be able to actively participate in AGU affairs without this support, since they will normally be traveling with the support of their home institution to participate in the scientific sessions. A very small fund is available to assist travel expenses incurred in connection with attendance at committee meetings held at other times. Individual commitments from this fund must be approved in advance by the executive director.

Some Current Activities

Statements by the current chairmen of several committees and the membership of these committees are given below to convey an overview of activities in the 1982–1984 biennium.

Committee on International Participation



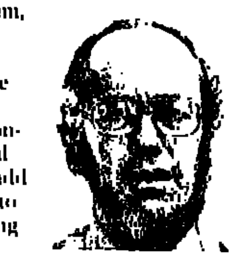
The principal initiative of the CIP for the current biennium is the development of an effective program for encouraging the geophysical sciences in Latin America by use of the mechanisms appropriate to a scientific society. We have begun to assemble a list of correspondents in Latin America, representative of the broad range of disciplines in AGU. We are in the process of creating a standing subcommittee on Latin America. This is a long range project and we aim for progress at a realistic rate, given the limitations on AGU resources for this purpose. We continue to maintain the excellent relations that have been developed with the European Geophysical Society, the Canadian Geophysical Union, and the Mexican Geophysical Union. We try to be alert to opportunities for constructive joint projects that we can carry out with these and other sister societies. We represent AGU in the Consortium of Affiliates for International Programs of AAAS. We continue our role in working out for Council consideration policy and practices related to AGU's participation in world science, especially AGU positions on matters of concern to the International Union of Geodesy and Geophysics. A task facing the CIP is the evaluation of the results of the Berkner membership program during the three years it has been in existence.

—*Carl Kisslinger*

Members

Carl Kisslinger, Chairman; Keiiti Aki; [illegible]

Budget and Finance



During this biennium, the main task of the budget and finance committee is to ensure that the operation of the Union makes a contribution to the capital fund. The goal is to add a total of $1,000,000 to the capital fund during the calendar years 1981–1985, or an average of $200,000 a year. So far, this goal has been exceeded during each of the first 2 years, and it is our intention that during the next 2 years we should achieve or exceed the goal. This is only possible by the cooperation of many individuals. First, a reasonable budget has to be prepared with the best estimates possible of meeting attendance, journal subscriptions, journal pages to be published, and all other major income or expense items. For the AGU budget to be met requires constant monitoring through the year by the executive director, the general secretary, and the heads of the various staff departments.

Major items of concern during the next 18 months are as follows. We wish to examine the performance of our investment advisers. We have decided to do this by comparing their performance with other indicators. For instance, our advisers certainly should be producing an increase in AGU capital funds which is greater than the rate of inflation. The increase should, in addition, be better than stock price indicators, such as the Dow Jones and Standard and Poor indicators, which are fixed groups of stocks. A better comparison is provided by looking at mutual funds, or mutual fund indicators. Another comparison which we hope to do is between the success of our advisers and that which can be gleaned for capital funds from other scholarly societies.

We need also to look at the dues structure. It is now clear that membership fees do not cover even the incremental cost of providing service to the member. Either the membership fee will have to rise, or the amount of service will have to decrease.

The books program has historically not been covering its direct and indirect costs. Pricing changes have recently been instituted in order to correct this. The committee will be studying the books program in order to see if these pricing changes are having the desired effect.

We are always concerned about the relative mix of income into the journals program, which consists of three main items: member subscriptions, nonmember (i.e., library) subscriptions, and page charges. Working with the Publications Committee we shall examine the mix to see if the long-term interests of the Union are being taken into account.

—*Christopher G. A. Harrison*

Members

Christopher G. A. Harrison, Chairman; Alexander J. Dessler; Arnulf Muan, Ned A. Ostenso, Marsha Torr, Leslie H. Meredith, ex officio.

AGU-GIFT Steering Committee

The members of the Steering Committee for AGU-GIFT express their sincere appreciation for the response of an increasing percentage of the AGU membership through their contributions. At the half-way point of the campaign nearly a third of the members have participated, yet we are far short of our goal: $1,000,000 by 1986. The Steering Committee plans to increase its efforts in urging the membership—particularly the senior members, the Fellows, the Medalists, and the former officers and chairpersons—to recognize the need for improving the AGU financial reserve position.

The acceptance of the '$10 voluntary contribution' on the dues invoices was greater for 1983 than for 1982 by almost 40%. The support by student members and those who have joined AGU since 1975 is remarkable. In the second half of the GIFT appeal we hope to more than double the number of Individual Supporting Members—those who contribute $100 annually ($80 plus the $20 dues). The goal is 250.

The real need is to increase the number of Life Supporting Members—those who contribute $1,500 or more during the 5 years of the appeal. A few are contributing $1,000 and more each year. A total of $5,000 provides recognition as Sustaining Member and $10,000 as Benefactor. If we are to achieve the goal of $1,000,000 we need many more in these categories. We need to persuade the affluent members—those who have prospered through their careers in geophysics—to transfer shares of stock or draw from their accumulations in money-market funds.

Further efforts will be made to urge members to recognize the opportunity for deferred giving—through bequests or the transfer of paid-up insurance policies. We will continue to emphasize that the AGU has grown and prospered because of unselfish cooperation by those who are concerned.

—*Charles A. Whitten and Earl G. Droessler*

Members

Earl G. Droessler and Charles A. Whitten, Co-chairmen; L. Thomas Aldrich; Cecil H. Green, J. Brackett Hersey, Jerome Namias, John C. Reed, Erick O. Schonstedt, Waldo Smith.

Statutes and Bylaws

It is the responsibility of this committee to assure that the statutes and bylaws of the Union are up-to-date and responsive to the needs of the membership. All proposed changes to the statutes and bylaws must be reviewed by this committee and presented to the Council with recommendations. In

Goals of the Union

The objectives of the Union are defined in the statutes as follows:

(a) To promote the scientific study of the earth and its environment in space and to make the results of such studies available to the public.

(b) To promote cooperation among scientific organizations whose objectives include the furtherance of knowledge in the geophysical disciplines.

(c) To initiate and participate in geophysical research programs, including those that depend upon international cooperation.

(d) To advance the various geophysical disciplines.

A set of working goals based on the Union's objectives has been developed. These are, in order of priority:

1. To provide media suitable for the dissemination of any sound scientific information related to geophysics and to assure that such information is accessible to individuals who have a use for it or an interest in it.

2. To stimulate scientifically productive personal relationships between and among geophysicists.

3. To encourage new relationships between and among subdisciplines of science that relate to geophysics.

4. To foster an increased awareness among individual scientists, worldwide, of what programs in geophysics are being carried out in each country and what the results are.

5. To attract competent individual students and research workers to devote their attention to geophysics, and to stimulate high-quality education for students interested in geophysics.

6. To assist individual geophysicists in their efforts to assure a political, social, and economic environment conducive to increased excellence in geophysical research.

addition it has been customary for this committee to review the organizational and governing documents of any section or region that might form and suggest changes if appropriate.

The objectives for this committee during the 1982–1984 biennium emphasize (1) a complete review of the Union's Statutes and Bylaws and proposing of needed changes, and (2) working with the sections in developing section bylaws that will provide individualized operating guidelines for each section. Several changes for the Union Statutes and bylaws have already been proposed and section bylaws have been approved for four of the sections. AGU members are urged to contact this committee with suggestions as to what statutes or bylaws should be changed (latest copy is in the August 31, 1982, issue of *Eos*).

Members —*A. Ivan Johnson*

A. Ivan Johnson, Chairman; Shelton S. Alexander, William C. Phinney, Joseph L. Reid.

Union Nominations

The Committee on Nominations is charged to present by spring 1983 two nominees each for the three major Union offices: President-Elect, General Secretary, Foreign Secretary. Committee members have placed some members in nomination. Although other Union members have submitted names, membership participation in the nominating process has been disappointing. Presently the Committee is firming up its final choices.

Members —*H. E. Landsberg*

Helmut E. Landsberg, Chairman; Allan V. Cox, Arthur E. Maxwell, Lynn R. Sykes, James R. Wallis, J. Tuzo Wilson.

Publications

The AGU Publications Committee oversees the publications program: journals, books, and translations. The committee routinely monitors the AGU staff support for these operations, defines policies and procedures, evaluates the sources of revenue for the publications program, and participates in the selection process for new editors. In addition to these continuing tasks, the committee has several special objectives for the 1982–84 biennium. These are:

(1) To maintain and enhance AGU's publishing reputation by the selection of outstanding editors and by ensuring high standards at each stage of the publishing process.

(2) To be alert to new opportunities for publishing ventures of use to geophysicists. Oceanography, seismology, and volcanology are evolving particularly rapidly and may invite AGU publication initiatives.

(3) To prepare for the increasing impact of the 'electronic age' on publications by investigating electronic document transfer, indexing, and access.

(4) To reevaluate the mix of income to the publishing program from individual subscription, library subscription, and page charges.

(5) To attempt to reduce manuscript processing and publication times without sacrifice in quality.

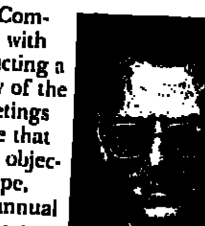
(6) To establish a detailed accounting scheme for AGU book sales projections and finances.

—*T. E. Graedel*

Members

Thomas E. Graedel, Chairman; David Atlas, M. Grant Gross, Jurate M. Landwehr, Peter H. Molnar, George C. Reid, Rob Van der Voo.

Meetings



The Meetings Committee is charged with the task of conducting a continuing review of the AGU's entire meetings program to assure that it supports Union objectives in depth, scope, and quality. The annual Spring and Fall meetings are the most important elements in this program, which the committee evaluates with the following questions in mind:

(1) Have these meetings provided the best possible forum for the communication of the results of on-going research in order to attract as large a fraction as possible of the active research community?

(2) Has personal contact among individual scientists been enhanced?

(3) Has an interdisciplinary understanding been enhanced?

(4) Have discussions of 'health of the science' issues been encouraged?

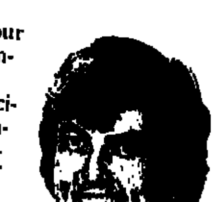
(5) Have these meetings succeeded in serving as an educational forum for scientists to broaden their understanding of the scope of geophysical research?

The Committee is charged with recommending policies regarding all meetings to the AGU Council. The Committee also pursues a program for stimulating, planning, conducting, and reviewing Chapman Conferences so that this series encompasses the interests of all sections and so that they are vigorous, financially self-supporting, and maintain their present reputation for excellence.

Members —*Thomas A. Potemra*

Thomas A. Potemra, Chairman; G. Brent Dalrymple, Thomas J. Fitch, Dennis W. Moore, Martin A. Pomerantz, Mary Lou C. Zoback.

Public Affairs



Responsibilities of our committee currently include selection of the AGU Congressional Science Fellow, dissemination of public information, and convening of symposia on issues of public interest at national meetings. In response to perceived immediate interests, the Public Affairs Committee selected two new initiatives to propose to Council at the December 1982 meeting:

(1) Inauguration of a program of science/policy seminars on college campuses, designed to capitalize on the experience gained by AGU's Congressional Science Fellows and others within our ranks who have been involved in the policy making process.

(2) Adding systematic coverage in *Eos* of pending and enacted governmental decisions relating to science in general and earth science in particular.

Purposes of the proposed seminar program are: (*a*) to enhance scientists' understanding of science policy issues; (*b*) to increase AGU visibility on college campuses; (*c*) to use effectively the special expertise gained by Fellows (and others); (*d*) to contribute to general understanding of legislative and executive (e.g., Office of Management and Budget) decision making processes among present and prospective scientists; (*e*) to increase awareness of the Congressional Science Fellowship program and expand the pool of interested candidates; and (*f*) to provide a visible 'return' on the Union's investment in the Congressional Fellowships. Presentations will focus on a specific science issue and its commonly tortuous path through the legislative mill.

The first initiative was approved by Council on a 2-year trial basis. The second initiative is not new, but its implementation has been haphazard at best, primarily because funds have not been sufficient to permit an *Eos* staff writer to cover Capitol Hill adequately. Council approved a budget allocation to support the additional staff time necessary for this effort and we have begun to see regular reports of Congressional and other governmental actions.

In addition, Fred Spilhaus agreed to initiate contact personally with staffs of Congressmen, Senators, and key committees to apprise them of the expertise within AGU that might be called upon for input when relevant legislation is under consideration. Headquarters has on file a list of 'issue spokesmen' willing to lend time, talent, and testimony.

We intend to continue to promote public-issues symposia. For the 1983 Spring meeting, the ball has been picked up by Lynn Sykes and Jack Evernden, who are organizing a session on verification of nuclear test bans. Topics under consideration for later meetings include radioactive waste disposal, hazards (natural and otherwise), and world habitability factors; additional suggestions are happily received.

Our Subcommittee on Public Information, under the chairmanship of Ray Roble, reviews meetings abstracts for newsworthy content and advises accordingly those in charge of news releases.

The Subcommittee on Governmental and Legislative Affairs, chaired by former Science Fellow Chris Bernabo, has primary responsibility for selecting the Congressional Science Fellow.

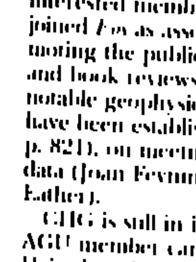
There appears to be decided consensus within our committee that more effective attention to and participation in public affairs and policy making by AGU members is not only appropriate but advisable. Our challenge is to devise effective means of stimulating among our colleagues this awareness and participation; we welcome comments and suggestions.

—*Carroll Ann Hodges*

Members

Carroll Ann Hodges, Chairman; Thomas J. Ahrens, Robert J. Barbera, J. Christopher Bernabo, David P. Cauffman, Jared L. Cohon, Stamatios M. Krimigis, Robert E. Murphy, Raymond G. Roble, George Shaw.

Annual Meetings



The annual AGU meetings are remarkable both in the level of attendance and in the broad scope of the topics discussed. They provide unique opportunities for scientists involved in the earth related sciences to meet with researchers in related topics and to hear about research across the broad spectrum of these sciences.

My prime objective is to ensure that the meetings continue to provide these opportunities. No major change in format is required, although the trend toward increasing use of poster sessions must continue to ensure both the highest quality of presentations and that we do not overflow all but a few convention sites in the nation. The program chairmen of the individual sections for the meetings play an invaluable role in supporting greater use of posters.

All-Union sessions should continue to inform members about major themes or events in the geosciences. In addition the success of the fractals session at the 1982 Fall meeting indicates that discussions of narrower topics (e.g., specific mathematical techniques) that are important to researchers in many topics may be desirable. It is important that AGU members continue to suggest topics for All-Union or special sessions to the meetings chairman or to the individual members of the programs committees.

—*H. Frank Eden*

1983 Spring Meeting Committee

H. Frank Eden, Meeting Chairman; John M. Bane, Demos C. Christodoulidis, James T. Engelder, Miriam A. Forman, Ronald Lavoie, Peter W. Lipman, Emile Okal, Carle M. Pieters, John R. Ritter, Raymond G. Roble, Michael Schulz, Patrick T. Taylor, Bruce T. Tsurutani.

Fellows

The principal function of the Fellows Committee is to select from among AGU members those men or women who should, 'in recognition of their acknowledged eminence in some branch of geophysics,' be made Fellows. The committee is asked to select no more than 0.1% of the total membership for fellowship every year which works out to only 15 new fellows to be elected in 1983. Clearly, there are many more members who qualify for fellowship than can be elected every year. Compounding the committee's difficulties is the fact that as a percentage of total membership in each section, some sections have too few fellows; others, too many. Should the committee try to correct the imbalance? In some sections there is much more current research activity than in other sections. Should the committee try to take that into account? Some sections of AGU feel that the sections should select the fellows, not an AGU Committee representing the entire membership. Would that be a better procedure? But perhaps the biggest problem encountered in the selection of new fellows is simply indifference on the part of the membership. Many eminent members are not elected to fellowship because nobody bothers to nominate them. Therefore, I urge you to send nominations of people you think qualify for fellowship.

The Fellows Committee is also looking into some other questions. Are the medals of the Union distributed reasonably over all the disciplines represented in the membership? Should there be more awards? Should the present awards be given more frequently or less frequently?

AGU awards are important. The Committee is currently considering the kind of questions I have outlined above. We need your advice and suggestions. Please send them to us.

Members —*Manik Talwani*

Manik Talwani, Chairman; James E. Faller, R. Allan Freeze, J. Freeman Gilbert, Donald Gurnett, James R. Holton, Richard H. Jahns, W. Barclay Kamb, Neil Opdyke, Robert O. Reid, Eugene M. Shoemaker.

History of Geophysics

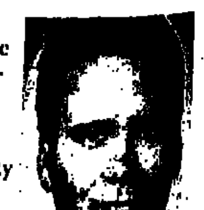
The Committee on the History of Geophysics (CHG) was established by the AGU council in December 1981 and is still in statu nascendi, exploring various activities and options toward achieving its goals. These include special sessions devoted to the history of geophysics, at least one per AGU meeting: in Spring 1982 on Solar-Planetary Relationships, Fall 1982 on Scientific Research During the IGY, and Spring 1983 on the History of Meteorology. A newsletter is being edited by George Siscoe (mailed to all interested members) and Bob Eather has joined *Eos* as associate editor for history, promoting the publication of relevant articles and book reviews and also of obituaries of notable geophysicists. Three subcommittees have been established (*Eos*, October 19, 1982, p. 821), on meetings (Martin Walt), historical data (Joan Feynman), and publications (Bob Eather).

CHG is still in its initial evolution and any AGU member can join it (contact Jim Heirtzler). In particular, CHG solicits participation from all those AGU sections which, for one reason or another, are still not adequately represented. Inputs and contributions to *Eos* are most welcome, including those related to obituaries, where Bob Eather is trying to cut any delays to the minimum. In the coming years CHG plans to promote (in addition to items already listed) publications related to geophysics, collaborations with academic historians of science, specific history research projects, archiving and indexing of historically valuable material, the history of AGU itself, and perhaps steps towards a permanent center devoted to the history of geophysics. Come with us, your participation is appreciated!

Members —*David P. Stern*

David P. Stern, Chairman; Harold L. Burstyn, Alexander J. Dessler, John A. Eddy, Joan Feynman, James R. Heirtzler, Martin Walt.

Atmosphere and Space Electricity



The Committee on Atmosphere and Space Electricity (CASE) currently serves three groups of scientists within AGU: (1) the thunderstorm electricity group, (2) the fair-weather atmospheric electricity group, and (3) the middle atmosphere electricity group. There is some overlap in these groups, but to a large extent the individuals align themselves within these subject areas. One of the functions of our committee is to promote communication between these groups and within the larger AGU membership. The membership of the committee represents all of these areas; this is certainly a feature that should be maintained in the makeup of future CASE membership.

The thunderstorm electricity group is one of the larger and more active groups in the Atmospheric Sciences Section of AGU; at AGU Fall meetings typically 30% of the atmospheric Sciences sessions are produced by this active group of research scientists.

The 'fair-weather' atmospheric electricity group (global circuit, ion reactions, etc.) interacts with both the thunderstorm and the middle-atmosphere groups. This group is small and frequently their papers are mixed with those of one of the other groups at AGU meetings. This group also provides with a link to Atmospheric Chemistry.

The middle-atmosphere electricity group is really a subset of the ionospheric, aeronomy, and magnetospheric groups; these scientists are usually in the Solar-Planetary Relationships (SPR) Section of AGU. Our committee has organized special sessions for this group that are cosponsored by Atmospheric Sciences and SPR. This has provided this group with the opportunity to present their papers to a broader AGU audience.

Over the past several years, CASE has (1) arranged special sessions at AGU meetings, (2) held annual committee meetings to provide a communication link among the AGU membership and between the membership and the AGU organization, (3) assisted the Thunderstorm Research International Research Program (TRIP) in communicating with principal investigators by inviting their participation in annual committee meetings, (4) promoted the strengthening of the middle atmospheric electrodynamics research, and (5) acted as a common representative of the diverse research groups involved in atmospheric and space electrical research.

Our annual meetings are held during the Annual Fall Meeting of AGU in San Francisco. Although only committee members may vote, these meetings are open to the AGU membership, and participation in the discussions is open to all in attendance. The time and place of meeting is announced during the Atmospheric Sciences Sessions; anyone interested in attending can also obtain this information from any of the committee members.

—*Arthur A. Few, Jr.*

Members

Arthur A. Few, Jr., Chairman; Hugh J. Christian, Robert H. Holzworth II, E. Philip Krider, Nelson C. Maynard, Charles B. Moore, Raymond G. Roble, Lothar H. Ruhnke, W. David Rust.

Membership

There are a number of issues facing the Membership Committee, some that should be discussed and some that should be acted upon.

(1) There is some sentiment for structural changes in AGU. There has been a request for a Committee on Mineral Physics to respond to the interdisciplinary nature of this field. In addition, there are some questions about what the future of the Planetology Section should be.

(2) The composition of the Executive Committee has been brought into question. Should it be enlarged so as to be more representative of the sections? Should the Foreign Secretary automatically be a member?

(3) The Geophysics Research Board of the National Academy of Sciences has been changed to the Geophysics Research Forum (GRF). It will not operate committees in the future, but will serve as a platform for discussion of interdisciplinary activities. Should AGU take some sort of role in participating in the activities of GRF? What role? How and when?

(4) Interest has been expressed in an IGY program dealing with biogeochemical cycles and there will be a study at Woods Hole this summer on this subject. What should be the role of AGU?

(5) What should our position be with regard to advocacy?

(6) What should we be doing with regard to recruitment that we are not doing now? In this regard, we need to consider foreign members, institutional membership, student members.

(7) How can we gain better interaction with academic departments at Universities? Should we try to establish designated correspondents at Universities?

(8) AGU is not currently a member of the American Geological Institute (AGI), and there are questions that need to be resolved before AGU might consider suggestions that it rejoin AGI.

—*Charles L. Drake*

Members

Charles L. Drake, Chairman; L. Thomas Aldrich, Louis J. Battan, E. R. Engdahl, James J. O'Brien, M. Gordon Wolman.

AGU on Capitol Hill: Cobalt Policy

Editor's Note: Following his term as an AGU Congressional Fellow, Robert J. Barbera served as a policy analyst in the Congressional Budget Office (CBO), where he wrote a study on Cobalt: Policy Options for a Strategic Mineral. Below, Barbera discusses his experience as a Congressional Fellow and in the CBO, after which appears the Summary to his 35-page report. Released in September 1982, the report is available from the CBO or from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

As the 1979–1980 AGU Congressional Science Fellow, I spent an exciting year working in the personal office of Senator Paul E. Tsongas (D-Mass.). My academic training provided me with an important analytical framework from which to approach issues. The Senate, of course, knows no disciplinary bounds, and limited staff size precludes concentration on a single issue; hence I found myself responsible for a wide range of subjects. Nonetheless, I believe that being comfortable with analytical approaches to evaluating problems enables a Congressional Fellow to participate effectively in the necessary political processing of many diverse issues.

Subsequent to my 2-year effort in Sen. Tsongas' office I spent a year with the Congressional Budget Office (CBO). During my stay there I came to appreciate the unique opportunity to focus on the art of political decision making that my fellowship had afforded me. Moreover, I believe that my years on Capitol Hill—made possible by the AGU fellowship—helped me to shape my research at CBO to better suit the needs of Congressional offices.

The Congressional Budget Office, the Congressional Research Service, the Office of Technology Assessment, and the General Accounting Office are sister agencies that report to the Congress and perform applied research efforts at the request of Congressional Committees or, in some cases, Members of Congress. Although each agency has its own charter, they all share certain characteristics. All are in the business of providing analyses of politically contentious issues in accessible form. In some instances, original research is performed, in others existing research is merely summarized. An understanding of the needs of Capitol Hill decision makers is key.

For me, the opportunity to participate in such research efforts was fantastic. I found my research was well directed because I felt that I had a sense of the players that might use it. In the paragraphs that follow, AGU has reprinted the summary of the report I helped produce while at CBO. I believe the issue it addresses—policy options for a strategic mineral—may be of interest to AGU members.

Summary of Study

The vulnerability of the United States to disruptions in the supply of imported materials considered essential to industrial production has been of concern to policymakers throughout the post-World War II era. Cobalt is a prime example of such a "strategic mineral." Cobalt alloys are important to a number of U.S. industries, especially aerospace and defense, and short-run opportunities for substitution are limited. The bulk of the world's supply of cobalt originates in central Africa (primarily Zaire and Zambia, which hold 64% of the world's known cobalt reserves), a politically unstable region. At present, the United States produces no cobalt. Thus, aside from cobalt stockpiles and the recycling of used materials, the United States is completely dependent on imports. This gives rise to two kinds of vulnerability. The first is essentially military in nature: the possible need to wage a war in the absence of foreign supplies of cobalt. The second is economic: the effect on the economy of a disruption in foreign supply with an attendant sudden increase in price. The fourfold price increases during the late 1970s, and the worldwide scramble for cobalt supplies at that time, have given prominence to this second kind of vulnerability.

The Current Federal Position

The strategic stockpile, created to provide sufficient quantities of metals and materials for essential production during war, is below its current goals for many materials. In March 1981, the Administration initiated the purchase of 5.2 million pounds of cobalt for the stockpile—the first major purchase in 20 years. Taking a different approach, the Department of Defense announced in early 1982 that it was exploring the possibility of offering subsidies to U.S. mining companies to initiate production from otherwise uneconomic domestic cobalt ores. Congressional concern about possible cutoffs of cobalt imports prompted hearings before the Senate Banking Committee in October of 1981 focused on whether U.S. dependence on imports would justify subsidization of domestic production.

Analysis

This paper examines in detail both the future demand for cobalt in the United States and the potential for cobalt supply shortfalls. The analysis suggests that, although significant disruptions in the supply of cobalt are a possibility throughout the 1980s, the existence of the strategic stockpile ensures that their consequences would be limited to the increased financial costs faced by cobalt users. No major loss to the national company would be likely.

U.S. Cobalt Demand

Cobalt is usually employed as an alloy with other metals where it imparts qualities such as heat resistance, high strength, wear resistance, and superior magnetism to the materials that are formed. U.S. consumption of cobalt in 1980 totaled about 17 million pounds, mainly used among alloys for jet engines and stationary gas turbines, permanent magnets for electrical equipment, machinery, and nonmetallic applications.

Increases in Cobalt Prices and Resulting Demand Effects. During the late 1970s, cobalt prices rose from $5.60 per pound to $25.00 per pound ... $50.00 ... because of a combination of factors: military conflict in Zaire, expanding industrial economies, and a change in U.S. stockpile policy. The price increases had significant effects on U.S. cobalt demand, precipitating searches for substitutes, improved conservation, and increased recycling from scrap.

Over the 1977–1979 period, these adjustments accounted for an estimated 19% reduction in what would otherwise have been the demand for cobalt. The experience was, for consumers of cobalt, a vivid illustration of the potential for future cobalt price swings and supply shortfalls. Accordingly, many U.S. industry efforts to identify cobalt substitutes continue, in spite of recent price declines. As of May 1982, cobalt's price has fallen to $12.50 per pound.

Future Problems in the Cobalt Market

Demand for cobalt is extremely difficult to forecast because of the mineral's specialized applications. Year-to-year fluctuations in cobalt use are often dramatic. Given the high levels of activity expected in a number of industrial sectors that traditionally use cobalt, in particular aerospace and electronics, estimates of about 30 million pounds of cobalt use by 1990 appear reasonable, although the further development of cobalt substitutes could appreciably reduce this estimate. More importantly, the development of substitutes would reduce U.S. vulnerability to supply shortfalls.

Cobalt and Direct Military Conflict. U.S. involvement in a direct military conflict could conceivably result in a shutoff of cobalt supplies to the United States. Thus some contingency plan that will supply cobalt for defense purposes appears warranted.

Economic Vulnerability to Nonmilitary Shortfalls. Concentration of the world's cobalt reserves in central Africa suggests that the threat of price increases and supply disruptions will continue throughout this decade.

Significant adjustment to a supply disruption is possible. Private inventories and in-pipeline supplies would provide an initial buffer. Suppliers of cobalt unaffected by the political disturbance could also be expected to increase their output. Scrap recovery would also increase. Substitution possibilities exist for a number of cobalt uses, and some have already been applied; the price rises attending a shortfall should accelerate their introduction. These adjustments and others appear to be sufficient to limit the effects of supply shortfalls largely to the payment of higher prices for cobalt and its substitutes.

Potential Effects on the U.S. Economy. The financial costs of higher cobalt prices, although potentially devastating to particular cobalt users, appear inconsequential to the economy as a whole. Although severe shortfalls could generate tenfold price increases, these would amount to less than $2 billion in a $3 trillion economy, and the value of imports would be less than 5% of the costs of U.S. petroleum imports from OPEC countries in 1981.

Policy Options

The Strategic Stockpile for Wartime Use

The Strategic and Critical Materials Stockpiling Act of 1964 requires that stockpiling of cobalt be done in sufficient quantities to provide supplies necessary for military, industrial, and essential civilian needs for the fighting of a three-year war. Executive agencies have translated this directive into a stockpile goal for cobalt of 85.4 million pounds, about one-half of which has been stockpiled so far.

As previously noted, the costs of shortfalls to the United States are likely to be quite limited in peacetime. Nonetheless, the possibility of a cutoff of cobalt supplies in wartime justifies some contingency plan for defense purposes. The strategic stockpile, given current cobalt prices, is probably the least expensive solution. The government recently purchased cobalt at $15 per pound for the stockpile, a price significantly below the estimated $25 cost for domestically produced ores. Moreover, the protection afforded the stockpiled cobalt extends beyond the mandatory three years, since domestic ore bodies could be brought on-line within that time and greatly extend the years of protection afforded by the stockpile.

Finally, the recent development of significant substitutes for cobalt suggests that the stockpile goal may be in need of reevaluation. Any reduction in the goal would reduce the cost of the stockpile.

Alternative Policies

A number of alternatives to the present policy are conceivable:

- A separate "economic stockpile" that could be drawn upon to moderate cobalt price swings;
- Subsidies to induce domestic ore production;
- Increased federal funding for research and development to expand the supply of cobalt and its substitutes;
- Expanded access to public lands for the location and development of domestic ore; and
- Accelerated development of ocean mining to tap the vast stores of cobalt contained in marine manganese nodules.

Any of these alternatives would afford a certain degree of protection against supply hazards—but each would entail some cost.

An economic stockpile, designed to moderate the impact of cobalt price increases to U.S. users of cobalt, would be an expensive form of protection in relation to the limited nature of the costs of the United States associated with such increases. The same would be true of subsidies for domestic ore production.

Increased research and development efforts could enable U.S. consumers of cobalt to substitute other metals, and also expand cobalt supply possibilities. Judgements about the appropriate level for research and development funding are always difficult to assess. In any event, it is noteworthy that substitution of any metals helped to mitigate the impact of the 1977–1979 price increases.

It does not appear that cobalt's strategic importance should be a major consideration in decisions relating to public lands or accelerated ocean mineral development.

Hydrology to Name Grant Winner

Horton Research Grant

The Hydrology Section will announce at the 1983 AGU Spring Meeting the recipient of the first Horton Research Grant. The grant was established at the section's Executive Committee meeting at the 1982 AGU Fall Meeting. The $4,500 grant is to support research projects in hydrology and water resources by Ph.D. candidates in American institutions of higher education and is to be awarded annually to a single recipient. Appropriate topics would be in hydrology (including its physical, chemical, or biological aspects) or in water resources policy sciences (including economics, systems analysis, sociology, and law).

Other Fall Meeting Business

In other business at the Fall Meeting, the committee asked the AGU Council to reverse its decision to terminate the journal of *Soviet Hydrology: Selected Papers* and instead allow it to be reorganized to meet the approval of the Translations Board and the Hydrology Section Executive Committee. The AGU Council has approved continuation of the journal subject to reorganization plans to be approved by the Publications Committee and the Hydrology Executive Committee.

WRR Page Charges

The committee recommended to the AGU Publications Committee that the page-charge structure of *Water Resources Research* be changed. The recommendation asked that the first 10 pages of a paper be published free, with any page number greater than 10 charged at the existing rate (currently $125 per page). Furthermore, there would be no free reprints and there would be no page charges to authors submitting review papers. Editor Stephen J. Burges was to prepare the request to the Publications Committee.

Publishing in Eos

Ivan Johnson requested that the Hydrology Section make a concerted effort to increase publication activity in *Eos*. The Executive Committee suggested that the Hydrology Section Technical Committee chairmen should solicit articles from persons in their respective areas of interest and also perhaps report on interesting items from their meetings.

History and Heritage

The question of whether to establish a History and Heritage Committee for the Hydrology Section was discussed. Allan Freeze agreed to solicit possible members for such a committee and will report back to the Executive Committee meeting at the AGU Spring Meeting.

Water Resource Systems

Section President Peter Eagleson announced he had delayed naming a chairman of the Water Resource Systems Committee. He said that the committee was in dire need of reorganization and focus; he felt that the social scientists have not been active in supporting this committee due to the quantitative nature that the term 'systems' implies. Eagleson said he would attempt to restructure the committee in order to bring the social scientists back into the fold.

Technical Committee Reports

The Executive Committee agreed that it should receive reports from the technical committee chairmen concerning committee meeting activities, formations of special sessions, and proposed Chapman conferences.

David Male, chairman of the Snow and Ice Committee, reported that he may request that his committee be disbanded for lack of interest. He would inform the Executive Committee of his decision at a later time.

Chairmen of the section committees on Surface Runoff, Groundwater, Urban Hydrology, and Precipitation discussed their plans for topical meetings and for sessions at the 1983 AGU Spring and Fall meetings.